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OCEANOGRAPHIC AND ACOUSTIC CHARACTERISTICS OF THE DABOB BAY RANGE

Research & Engineering Department

November 1976

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By R. A. Helton

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The climatological, physical oceanographic, geologic and underwater acoustic characteristics of the Dabob Bay tracking range are described and quantified. These characteristics are intended to inform range users about the total range environmental subsystem.

The environmental subsystem can constrain the proposed testing of systems and this report presents significant data for test planning development. These constraints result from the unique estuarine environment of the Dabob Bay and Hood Canal province.

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1. INTRODUCTION

The purpose of this report is to make the physical oceanographic and acoustic characteristics of the Dabob Bay range known to range users and prospective users, who may then apply the information to specific projects.

The report includes chapters on climate, sound speed, acoustics, general parameters, and scheduling precautions. Included in the general parameters chapter are sections on density structure and on tides and currents.

The Dabob Bay range is one of five ranges operated by the Naval Torpedo Station. (For details, see NAVSEA OD 41964[1].) The others are the Jervis Inlet range, Nanoose range, Hood Canal range, and Keyport range. Dabob is fundamentally a three-dimensional (3-D) underwater acoustic tracking range; however, optical in-air tracking capability is also offered.

The Dabob Bay range is located off Hood Canal and is situated a short distance west of the Naval Submarine Base, Bangor. The range is presently 12,000 yards long and 2,500 yards wide. Maximum water depth is around 600 feet. Figure 1 indicates the location of the range and Figure 2 illustrates the approach to Dabob Bay. The range tracking area, its bathymetry, and its instrumentation sites are shown in Figure 3.

Dabob Bay is unique in the variability of its water characteristics of salinity and temperature. This variability results from intrusions of coastal Pacific Ocean water into the bay. A cellular, non-homogeneous water mass results. This water mass then responds by internal circulative processes to attain a more homogeneous state.

The various states/conditions of Dabob waters have been described by several investigators and the scientific results are referenced in this report (see Kollmeyer's thesis[2] and Ebbesmeyer's thesis[3]). A description of the end result, as it

[1]NAVSEA OD 41964 Revision 1, *NAVTORPSTA Range Users' Guide*, July 1975, unclassified

[2]*Water Properties and Circulation in Dabob Bay - Autumn 1962*, Ronald C. Kollmeyer, M.S. thesis, University of Washington, Seattle, WA, 1965, unclassified

[3]*Some Observations of Medium Scale Water Parcels in a Fjord: Dabob Bay, Washington*, Curtis C. Ebbesmeyer, Ph.D. thesis, University of Washington, Seattle, WA 1973, unclassified

affects device ranging and underwater acoustics, is what the range user needs and this will be addressed after a discussion of pertinent climatological characteristics. Range use logistical topics are discussed in NAVSEA OD 41964.

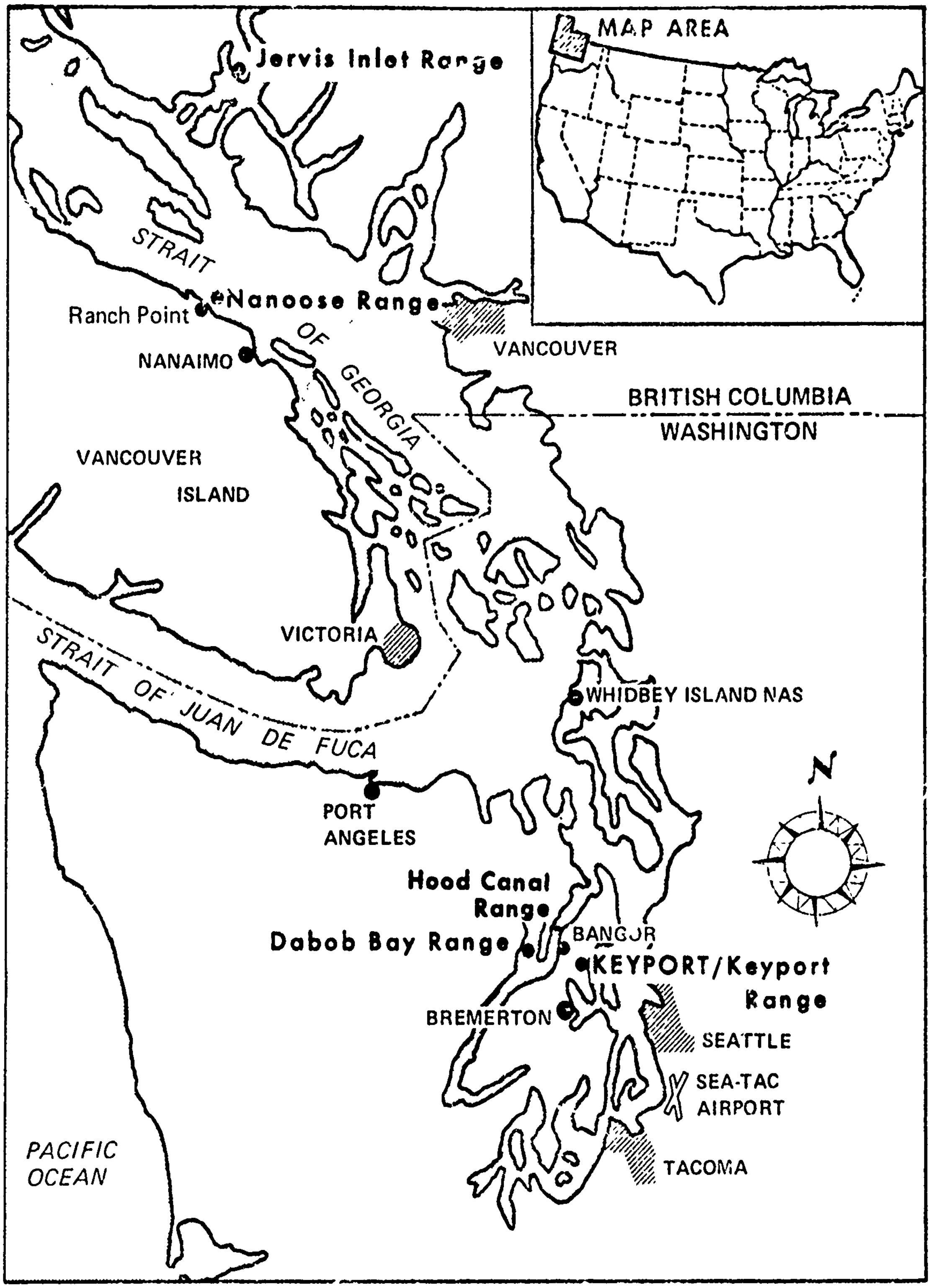


Figure 1. General Location of Dabob Bay Range

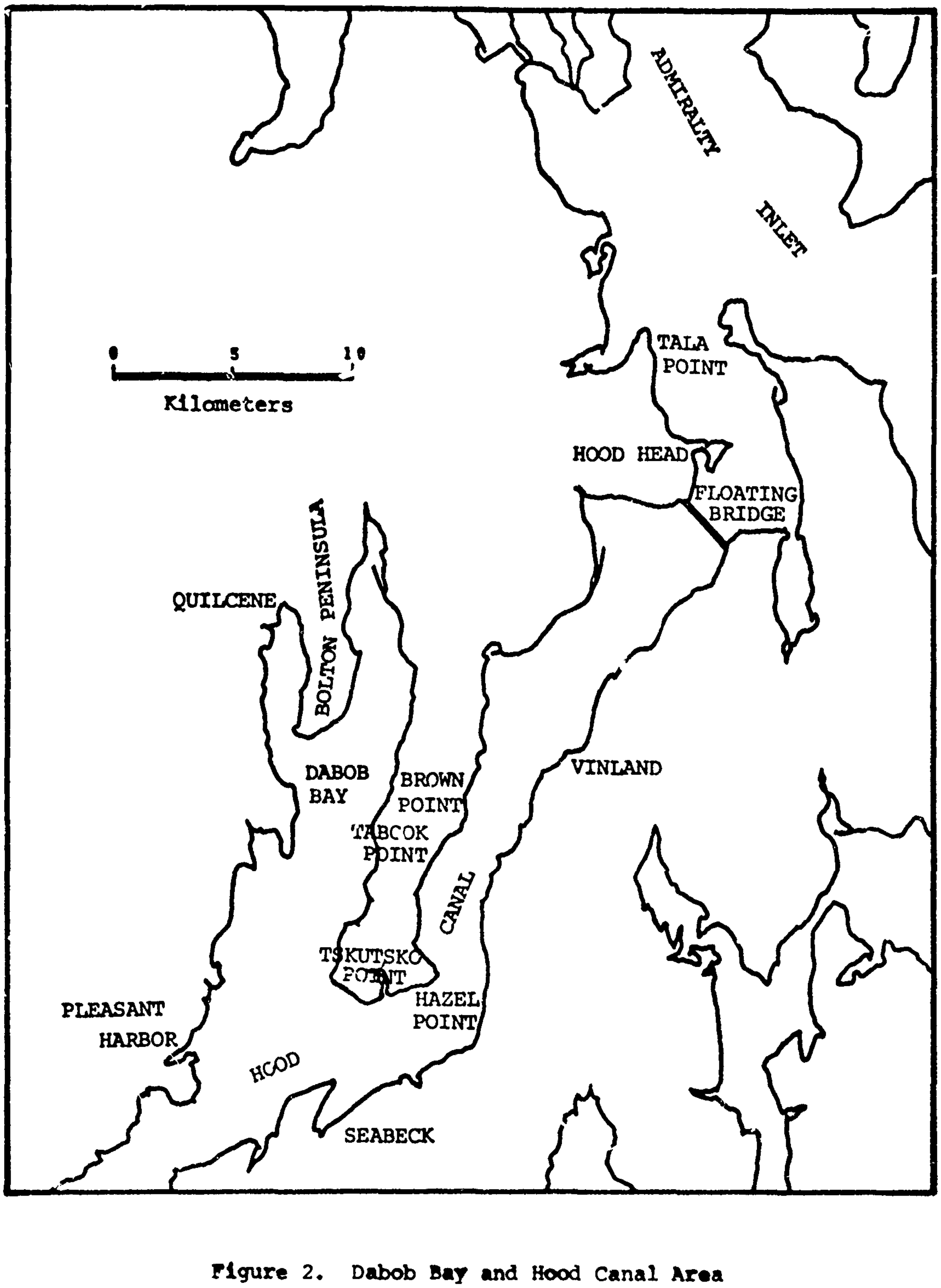
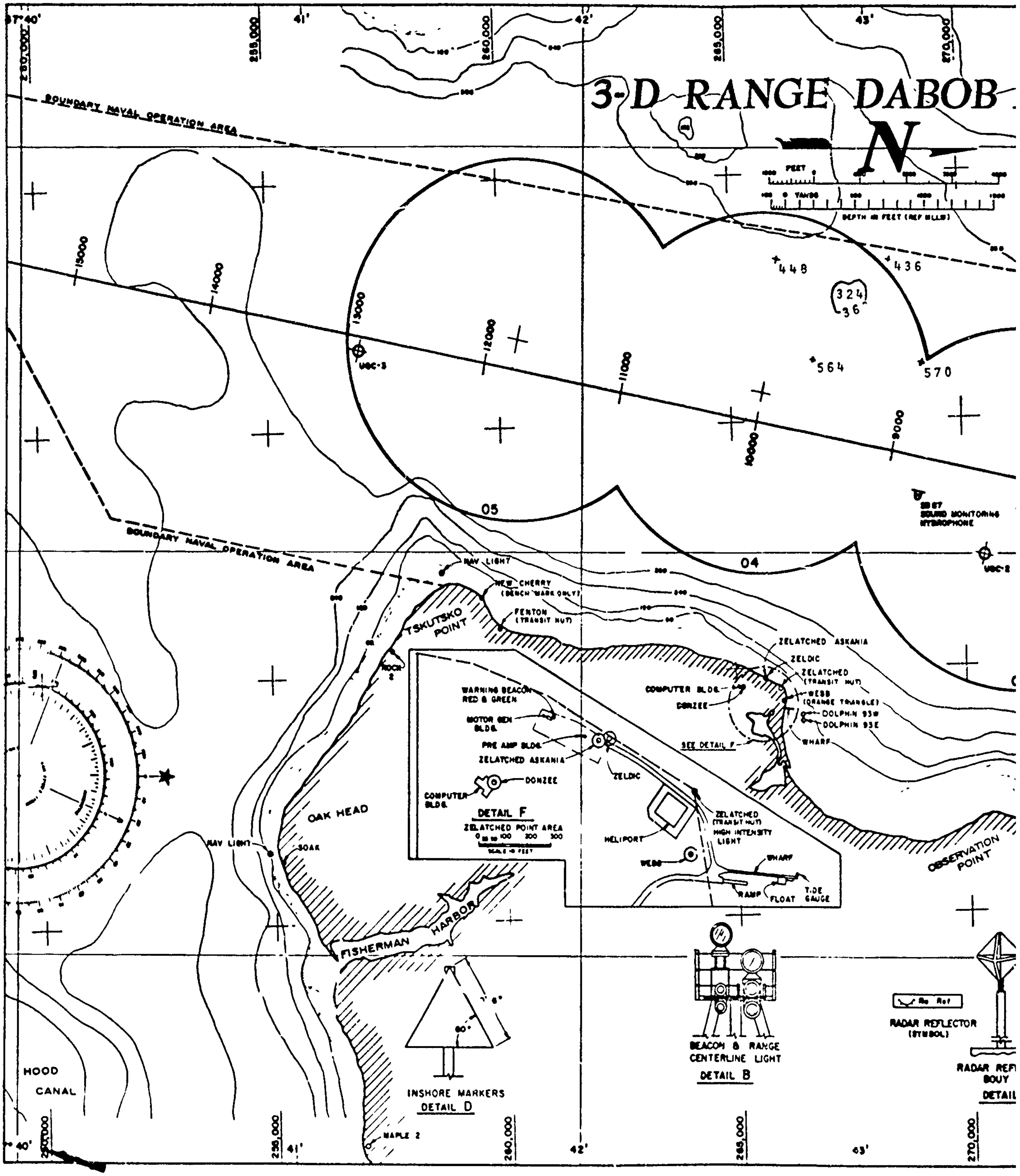
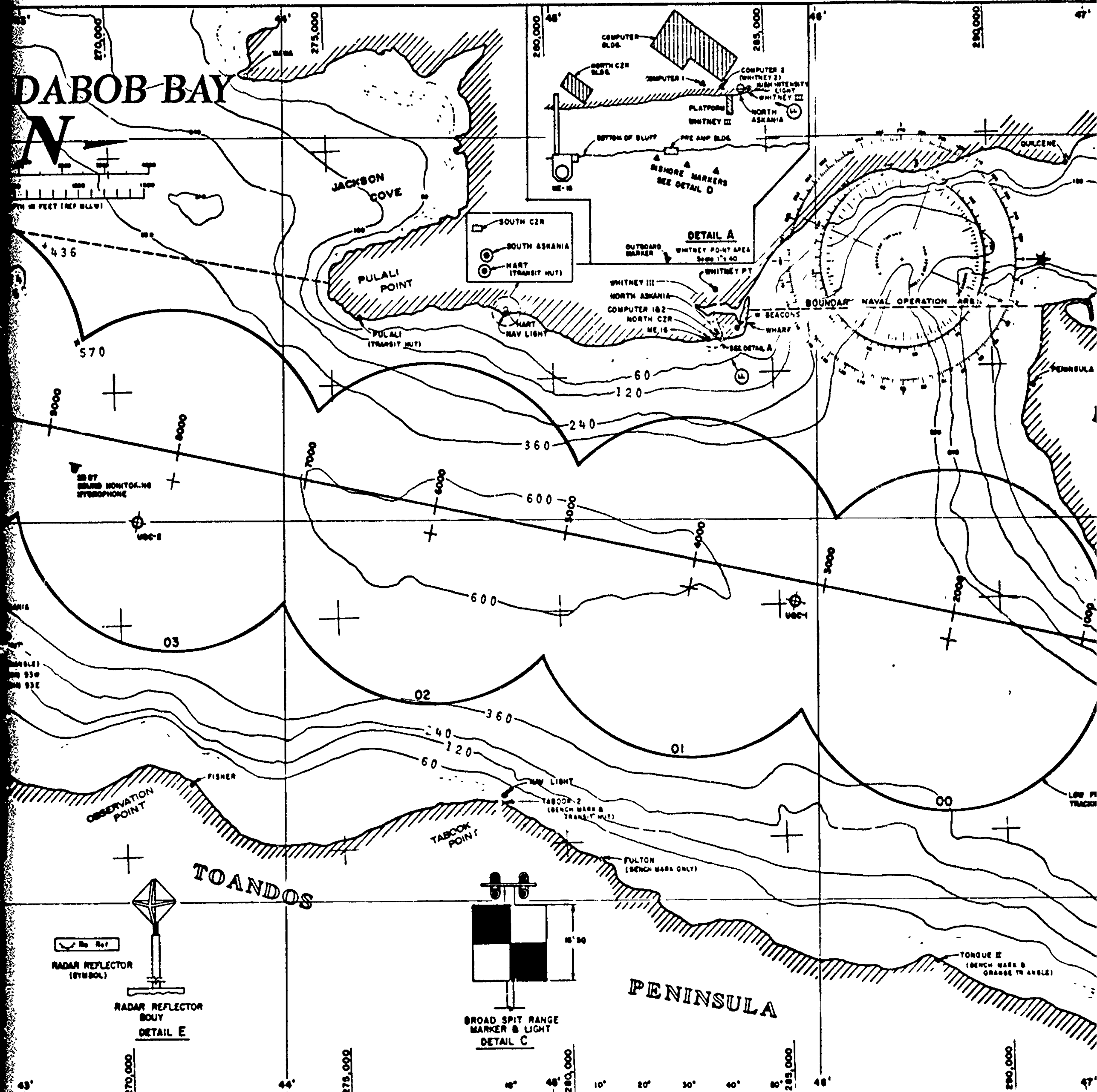


Figure 2. Dabob Bay and Hood Canal Area


3-D RANGE DABOB
N
FEET
YARDS
DEPTH IN FEET (REF MLLW)
BOUNDARY NAVAL OPERATION AREA
BOUNDARY NAVAL OPERATION AREA
UGC-3
UGC-2
05
04
SOUND MONITORING HYDROPHONE
NAV LIGHT
NEW CHERRY (BENCH MARK ONLY)
FENTON (TRANSIT HUT)
TSKUTSKO POINT
ROCK 2
ZELATCHED ASKANIA
ZELDIC
ZELATCHED (TRANSIT HUT)
WEBB (ORANGE TRIANGLE)
DOLPHIN 93W
DOLPHIN 93E
WHARF
COMPUTER BLDG.
DONZEE
SEE DETAIL F
WARNING BEACON RED & GREEN
MOTOR GEN BLDG.
PRE AMP BLDG.
ZELATCHED ASKANIA
ZELDIC
DONZEE
COMPUTER BLDG.
DETAIL F
ZELATCHED POINT AREA
SCALE IN FEET
ZELATCHED (TRANSIT HUT)
HIGH INTENSITY LIGHT
HELIPORT
WEBB
WHARF
RAMP
FLOAT
TIDE GAUGE
OAK HEAD
NAV LIGHT
SOAK
FISHERMAN HARBOR
OBSERVATION POINT
HOOD CANAL
INSHORE MARKERS
DETAIL D
BEACON & RANGE CENTERLINE LIGHT
DETAIL B
RADAR REFLECTOR (SYMBOL)
RADAR REFL BOUY
DETAIL
MAPLE 2
250,000
255,000
260,000
265,000
270,000
40'
41'
42'
43'

2



DABOB BAY
N
JACKSON COVE
PULALI POINT
SOUTH CZR
SOUTH ASKANIA
HART (TRANSIT HUT)
DETAIL A
WHITNEY POINT AREA
PLATFORM WHITNEY III
NORTH ASKANIA
COMPUTER BLDG.
NORTH CZR BLDG.
PRE AMP BLDG.
BISHORE MARKERS SEE DETAIL D
WHITNEY PT
WHITNEY III
NORTH ASKANIA
COMPUTER 1&2
NORTH CZR
BEACONS
WHARF
SEE DETAIL A
BOUNDARY NAVAL OPERATION AREA
PULALI (TRANSIT HUT)
HART NAV LIGHT
DUCKABUSH
PENINSULA
LOW FI TRACKI
USC-2
USC-1
03
02
01
00
600
360
240
120
60
NAV LIGHT
FISHER
OBSERVATION POINT
TABOOK POINT
TABOOK 2 (BENCH MARK & TRANSIT HUT)
FULTON (BENCH MARK ONLY)
TOANDOS
PENINSULA
TONGUE II (BENCH MARK & ORANGE TR ANGLE)
RADAR REFLECTOR (SYMBOL)
RADAR REFLECTOR BOUY
DETAIL E
BROAD SPIT RANGE MARKER & LIGHT
DETAIL C
270,000
275,000
280,000
285,000
290,000

Figure 3

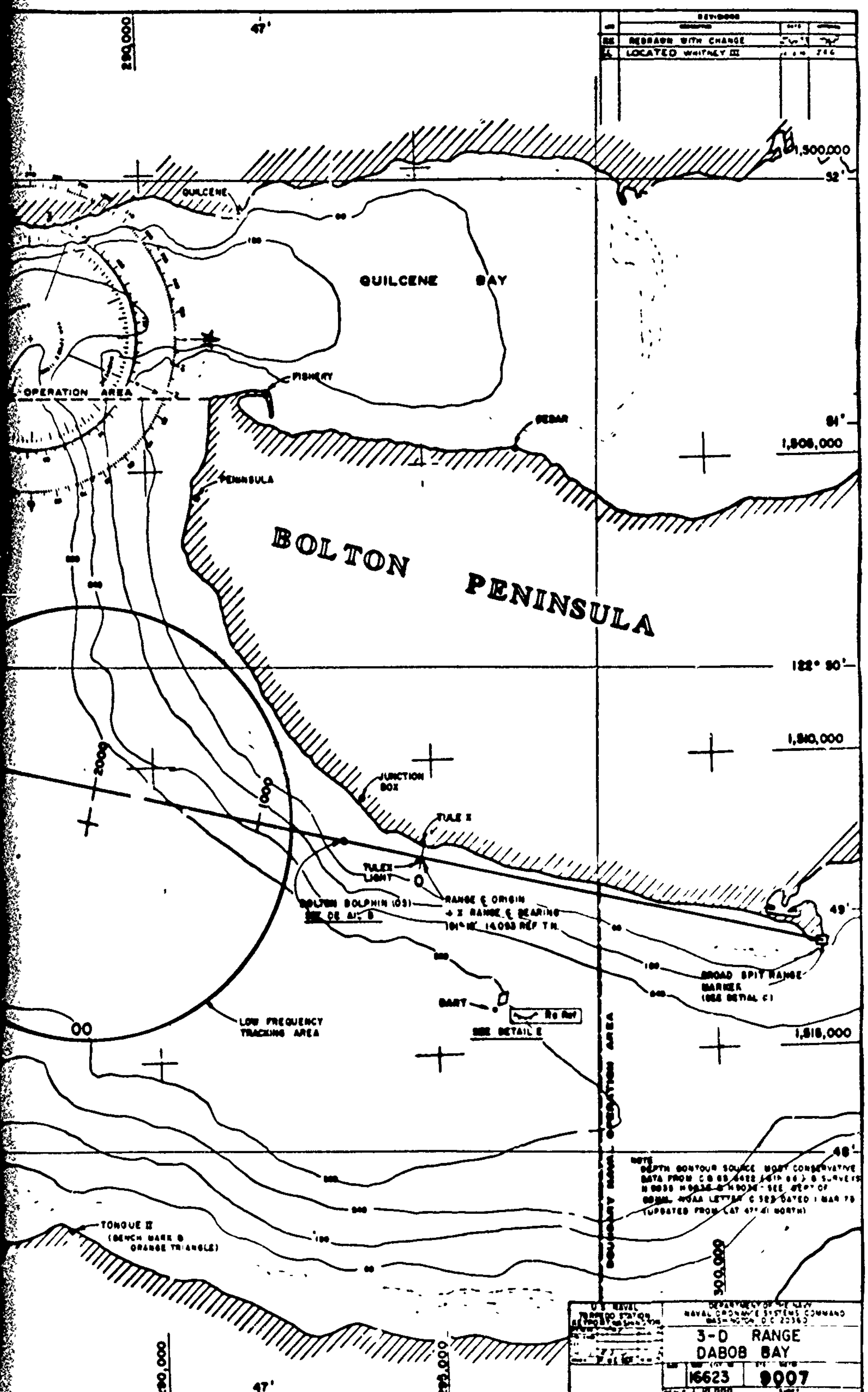


Figure 3. Dabob Bay Instrumented Operating Area

2. CLIMATE

This chapter describes the climate of the Dabob Bay and Hood Canal region and its effect on the water characteristics. Much of the information was obtained from Phillips' *Washington Climate*[4], National Climatic Center[5], and U.S. Weather Bureau[6]. The surface-wind characteristics were developed from Technical Report No. 37[7], AWA/ABAM joint venture[8], U.S. Weather Bureau[9,10], and *in-situ* data records.

A. AIR TEMPERATURE

The air temperature cycle is in phase with the annual heating and cooling cycle of the near-surface to surface water layer. In Hood Canal, for example, the near-surface water layer warms around 5.5°C for an average air temperature increase of around 13°C. Temperature changes at this and greater depths are shown in Figure 4. Typical monthly mean air temperatures for a yearly cycle at two weather stations, Sea-Tac airport and Bremerton, are given in Figure 5. Also shown in Figure 5 is the yearly cycle for solar radiation.

Daily maximum and minimum temperature excursions from the monthly mean range from ±3°C in winter to ±6°C in summer. Thus,

[4] *Washington Climate*, Earl L. Phillips, Cooperative Extension Service, College of Agriculture, Washington State University, Pullman, WA, January 1968, unclassified

[5] *Local Climatological Data for Seattle Washington (Seattle-Tacoma Airport)*, National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Asheville, NC, 1974, unclassified

[6] *Climatological Summary for Bremerton Washington*, U.S. Department of Commerce, Weather Bureau, 1931-1960, unclassified

[7] Technical Report No. 37, *The Surface Winds over Puget Sound the Strait of Juan de Fuca and their Oceanographic Effects*, Russell G. Harris and Maurice Rattry, Jr., University of Washington Department of Oceanography, July 1954, unclassified

[8] *Department of the Navy OICC TRIDENT Model Windtunnel Test Explosives Handling Wharf No. 1 - Final Report*, AWA/ABAM joint venture, Contract N68248-73-C-003, Adrian Wilson Associates, Los Angeles, CA and ABAM Engineers, Inc., Tacoma, WA, April 1975, unclassified

[9] *Climatological Summary for Coupeville - Oak Harbor Washington (Whidbey Island)*, U.S. Department of Commerce, Weather Bureau, 1931-1960, unclassified

[10] *Climatological Summary for Everett Washington (Paine Field)*, U.S. Department of Commerce Weather Bureau, 1931-1960, unclassified

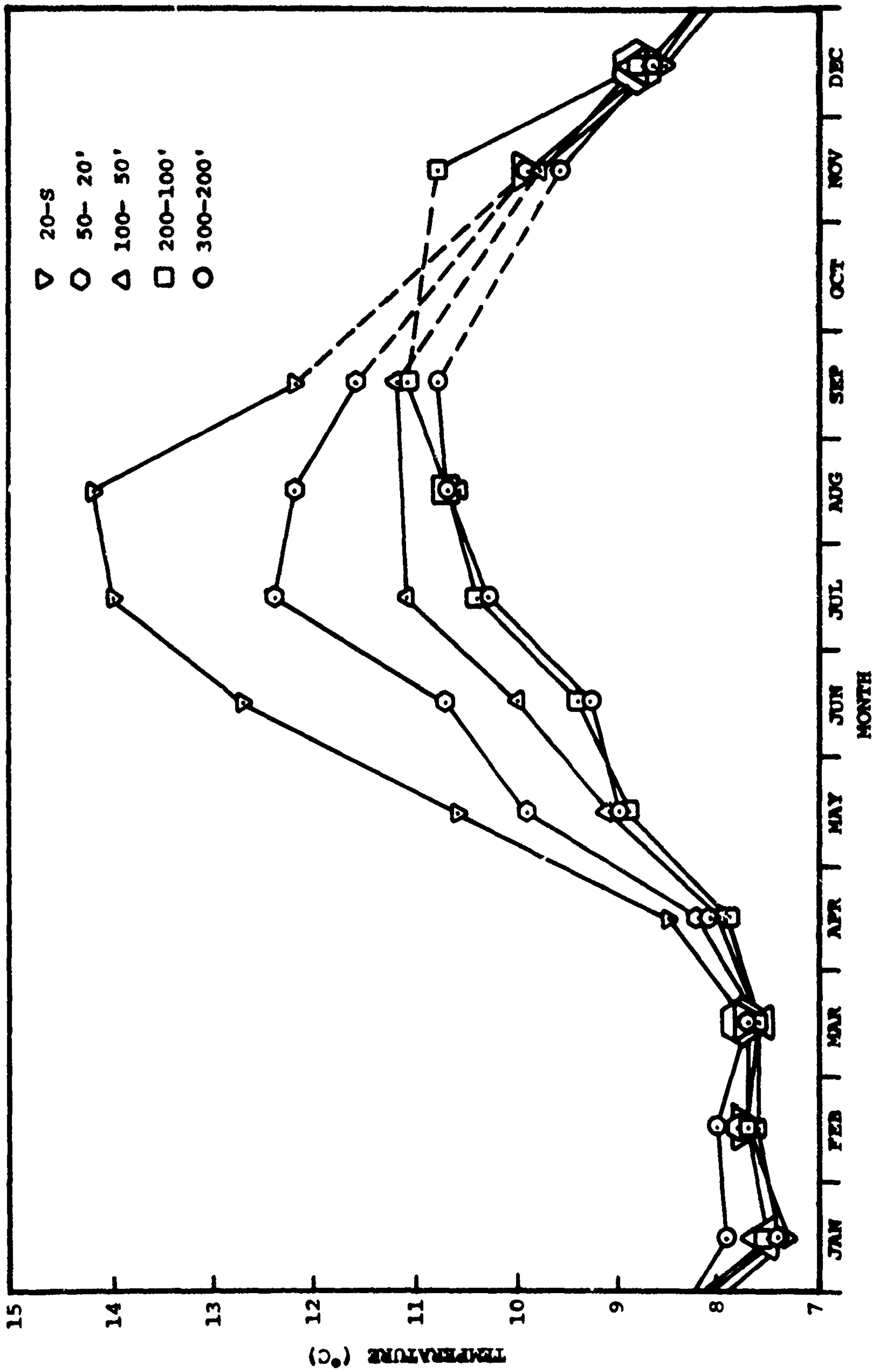


Figure 4. Hood Canal Averaged Monthly Stratum Temperatures
(Source: WSAT Sonar Buoy)

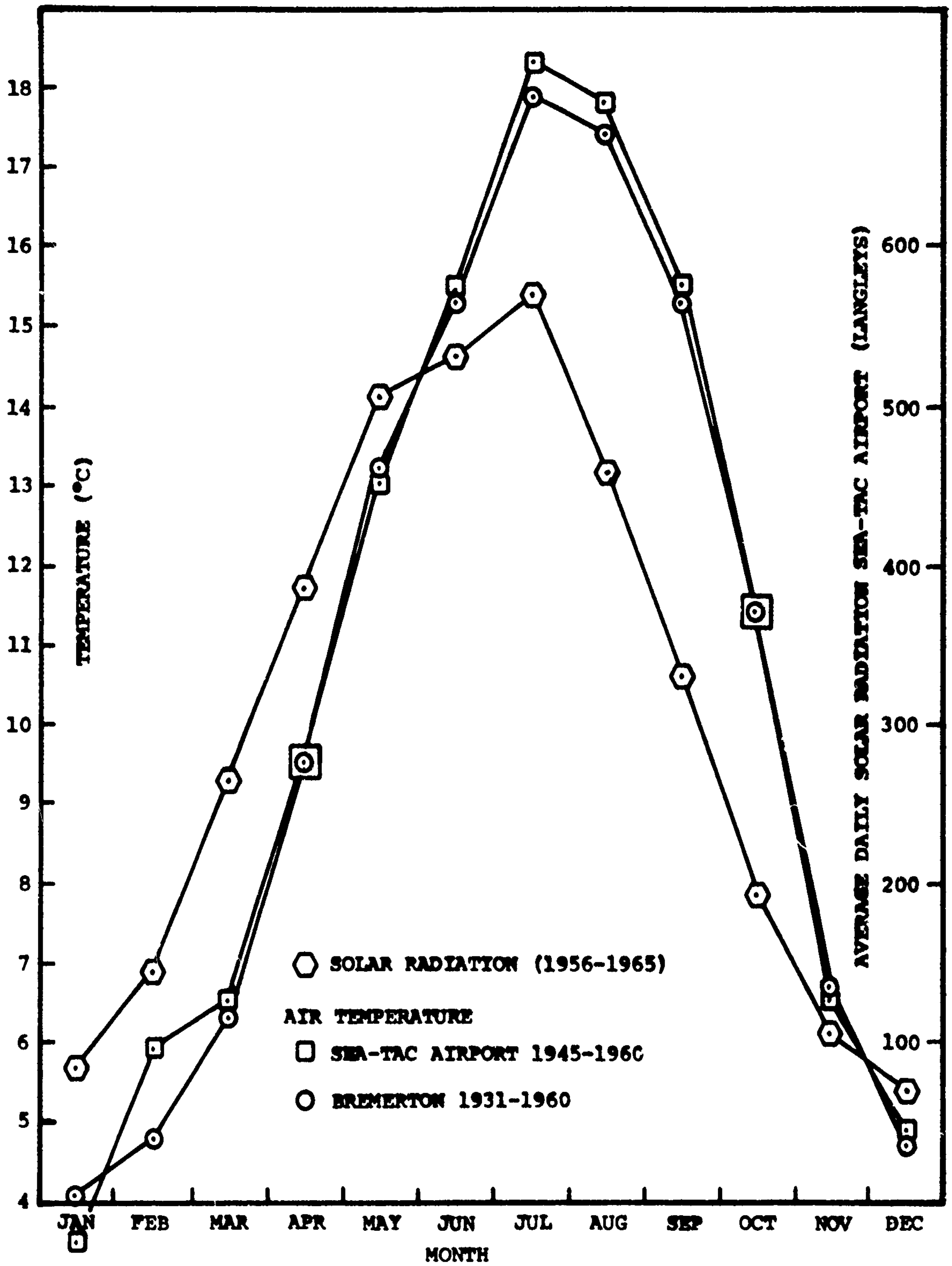


Figure 5. Air Temperature and Average Daily Solar Radiation

for example, an average maximum daily temperature in July is around 24.5°C (76.1°F) and an average minimum daily winter temperature in January is 1°C (33.8°F). Historical daily temperature deviations from the monthly mean temperature for Bremerton and Sea-Tac airport are given in Table 1.

From Figures 4 and 5 it can be observed that the sea surface temperatures, compared to air temperatures, are generally lower in summer and greater in autumn and winter. This thermal lag, representative of areas adjacent to large bodies of water, helps keep air temperature extremes below those encountered in non-marine environments.

B. PRECIPITATION

Precipitation can vary considerably as a function of location in the Dabob Bay region, which is heavily shadowed by the Olympic mountains. Figure 6, showing monthly mean precipitation at three stations close to the region, provides examples. The variability of precipitation at Bremerton is illustrated in Figure 7. The upper band edge of the data envelope defined by the records for Sea-Tac, Bremerton, and Keyport is considered representative of the mean monthly precipitation for the Dabob Bay region.

The applicability of Figure 6 for predicting Dabob Bay precipitation is reinforced by comparison with precipitation records now being obtained at Bangor during Trident construction.

Precipitation probabilities and rainfall intensities obtained from Phillips' *Washington Climate*, are provided as Tables 2 and 3.

Streams and rivers entering Hood Canal, including the Quilcene River, which enters an arm of Dabob Bay, reduce the surface-layer water salinity of the bay. The relative contributions of these sources are unknown because the low salinity surface waters of Hood Canal enter Dabob through tidal action. The combined sources, however, do maintain a low salinity surface layer in Dabob Bay the year around.

Maximum depression of surface salinity occurs in late winter to early summer, when the accumulation of runoff in the surface layer is greatest. Typical salinity profile envelopes for Dabob Bay are shown in the next chapter.

C. CLOUD COVER

The percentage prevalence of cloud cover greater than 0.8 is given in Figure 8 for Seattle. Cloud cover prevalences in the three ranges of 0-0.3, 0.4-0.7, and 0.8-1.0 are referred to as clear, partly cloudy, and cloudy conditions, respectively.

Table 1. Historical Temperature Characteristics
(Degrees centigrade)

DATA		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BREMERTON 1931-1960	Average Maximum	7.22	8.88	10.72	14.55	18.94	20.77	24.33	23.55	21.0	16.05	10.38	8.11
	Average Minimum	1.0	1.5	1.88	4.44	7.5	9.77	11.38	11.27	9.5	6.55	2.77	1.83
	Mean	4.11	5.22	6.33	9.5	13.22	15.27	17.88	17.44	15.27	11.33	6.61	4.72
	Highest	14.44	16.66	20.00	25.55	31.66	36.11	36.11	37.22	31.66	27.77	18.33	15.00
	Lowest	-9.44	-8.88	-6.11	-2.22	-1.11	4.44	5.00	4.44	2.77	-.55	-12.22	-5.55
SEA-TAC 1945-1960	Average Maximum	6.44	8.33	10.72	14.55	18.66	21.05	24.22	23.66	20.72	15.72	9.77	7.72
	Average Minimum	.55	1.38	2.33	4.50	7.38	9.83	12.27	12.0	10.27	6.88	3.38	2.05
	Mean	3.5	5.88	6.55	9.55	13.05	15.44	18.27	17.83	15.50	11.33	6.61	4.88
	Highest	16.11	20.00	21.66	25.00	33.88	32.22	36.11	37.22	31.66	26.66	18.33	15.55
	Lowest	-11.11	-7.77	-5.00	-1.11	.55	5.00	7.77	7.22	3.88	-1.66	-5.00	-9.44
SEA-TAC 1941-1970	Mean	3.44	5.72	6.72	9.27	12.72	15.44	18.05	17.66	15.33	11.22	7.00	4.72
1973	Mean	3.72	6.61	6.72	9.22	13.61	15.16	18.16	16.44	16.61	11.22	6.5	6.88

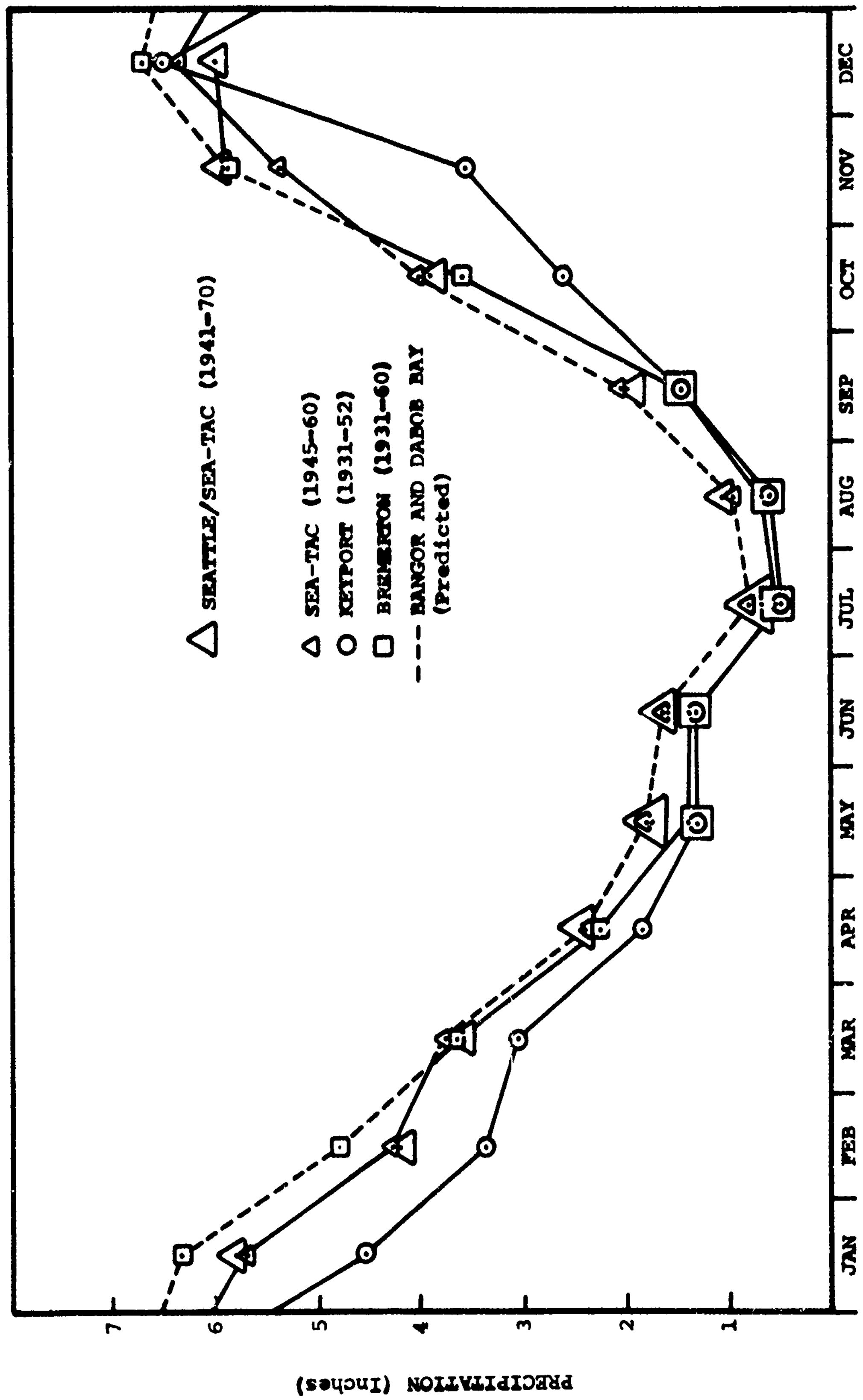


Figure 6. Average Monthly Precipitation

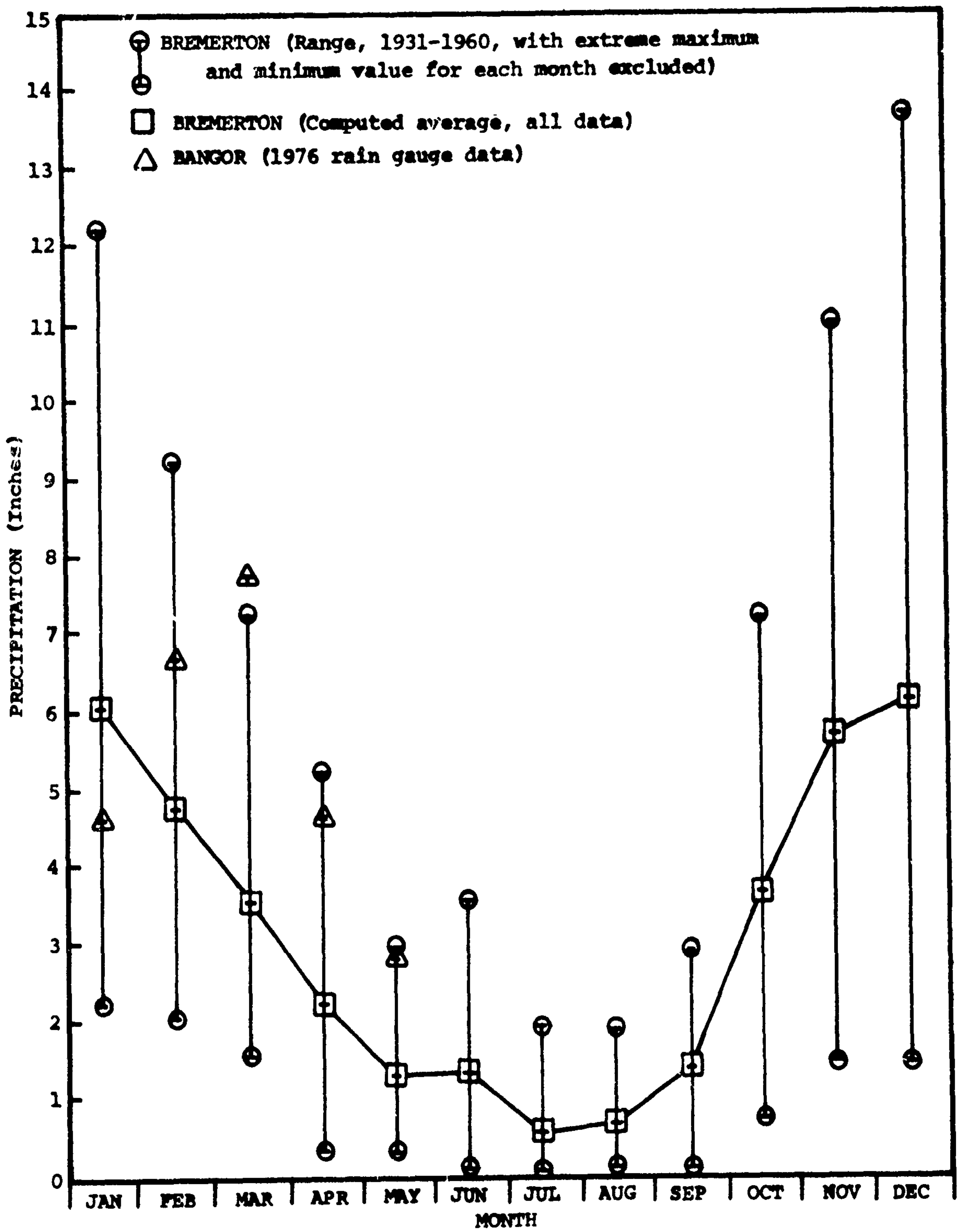


Figure 7. Precipitation Characteristics for Bremerton-Bangor Area

Table 2. Precipitation

Station	JAN Less Than	JAN More Than	FEB Less Than	FEB More Than	MAR Less Than	MAR More Than	APR Less Than	APR More Than	MAY Less Than	MAY More Than	JUN Less Than	JUN More Than
BREMERTON												
1 yr in 10	2.8	10.5	2.2	8.1	1.6	6.9	.4	4.6	.3	2.9	.1	[illegible].4
2 yr in 10	3.2	9.1	2.6	6.8	2.1	5.5	1.1	3.6	.5	2.1	.4	2.1
3 yr in 10	3.8	8.7	2.7	5.8	2.2	4.3	1.4	2.9	.8	1.7	.7	1.8
4 yr in 10	4.5	6.3	3.6	5.6	2.6	3.9	1.7	2.7	.9	1.5	1.0	1.3
SEATTLE CITY												
1 yr in 10	2.6	8.9	1.9	6.8	1.7	5.7	.6	3.0	.6	3.3	.2	3.0
2 yr in 10	3.0	7.6	2.0	5.7	2.1	4.4	1.2	2.6	.6	2.6	.4	2.3
3 yr in 10	3.5	6.3	2.3	5.5	2.1	4.0	1.6	2.4	1.0	1.8	.6	2.0
4 yr in 10	3.8	5.6	2.8	4.6	2.7	3.6	1.6	2.3	1.1	1.6	.9	1.6

Probabilities (Inches) (T = trace)

JUL		AUG		SEP		OCT		NOV		DEC		ANNUAL	
Less Than	More Than	Less Than	More Than	Less Than	More Than	Less Than	More Than	Less Than	More Than	Less Than	More Than	Less Than	More Than
T	1.4	.1	1.5	.2	2.9	1.5	7.2	2.0	9.8	3.5	11.0	24.0	54.8
.1	1.0	.1	1.1	.4	2.3	1.6	5.8	2.4	8.5	4.6	9.1	28.6	49.7
.2	.7	.2	1.0	.7	2.1	2.0	4.7	2.7	8.0	4.9	8.1	31.7	46.3
.3	.5	.4	.7	1.1	1.8	2.7	4.2	3.5	7.3	5.3	7.1	32.6	41.2
.1	1.4	.2	1.4	.2	3.0	1.0	5.5	1.5	8.3	3.0	8.5	23.0	44.0
.2	.8	.3	1.2	.6	2.9	1.9	4.7	2.7	7.5	3.6	6.6	31.0	38.2
.4	.8	.4	1.2	1.0	2.3	2.3	4.0	2.9	6.7	4.2	6.2	31.7	36.6
.6	.7	.5	.7	1.3	2.0	3.0	3.5	3.7	6.1	4.5	5.5	33.3	35.6

Table 3. Rainfall Intensities
(Precipitation in Inches)

PUGET SOUND LOWLANDS

	Return Periods				
Duration	2 yrs	5 yrs	10 yrs	25 yrs	50 yrs
30 Minutes	0.4	0.5	0.6	0.6	0.7
1 Hour	0.5	0.6	0.7	0.8	0.9
2 Hours	0.7	0.8	1.0	1.2	1.5
3 Hours	0.9	1.2	1.5	1.7	2.0
6 Hours	1.5	1.8	2.0	2.5	2.8
12 Hours	2.0	2.5	3.0	3.2	3.5
24 Hours	2.5	3.0	3.5	4.0	4.2
48 Hours	3.0	4.0	4.5	5.0	5.5
96 Hours	4.0	4.5	5.5	6.0	7.0

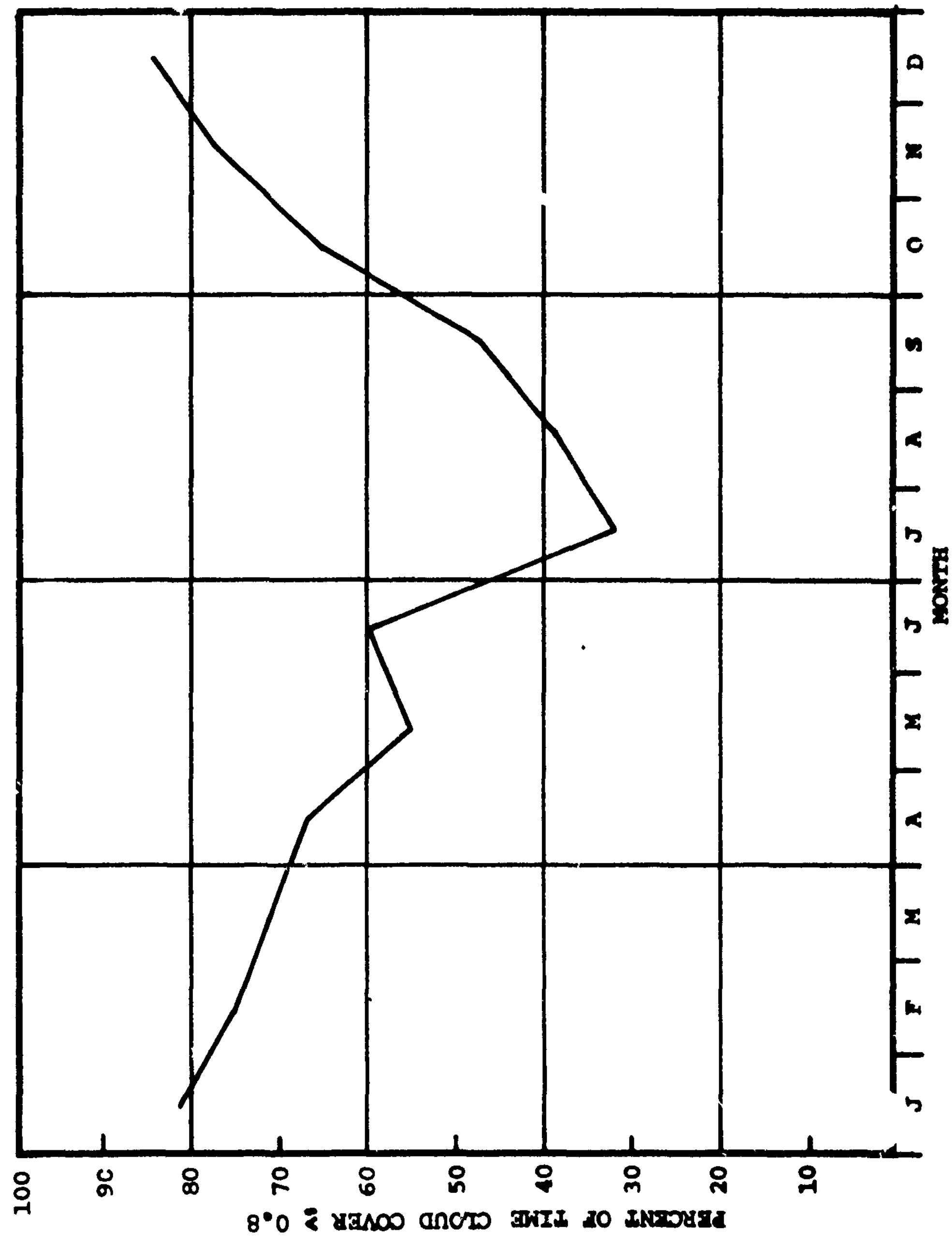


Figure 8. Mean Monthly Prevalence of Cloud Cover for Seattle (Thirty-year average. From reference 5)

D. WINDS

The wind in Dabob Bay is funneled through elevations of up to 600 feet on the north and east and several thousand feet on the west. The bay entrance is completely open to southerly winds and the central bay region is subject to Quilcene River valley winds. Severe but infrequent storms and funneling around the Olympic Mountains have produced extreme winds in Dabob Bay. Page 39 of Kollmeyer's thesis reports that winds frequently reached 80 mph during a 2.5-hour peak storm period. Three and one-half Dabob Bay lengths south at Olympia, Washington, the peak recorded southerly winds reached 58 mph.

To quantify the wind characteristics in Dabob, the available observations of wind speed and direction occurring during torpedo noise acquisition time periods were studied. These data comprise 150 documented observations from October 1972 to May 1976. All months except July and December were fairly well populated with data samples.

These data were analyzed and compared with other wind records. The data do not enable compilation of conventional monthly wind strength/duration tables but do support wind speed/frequency estimates.

Speeds of less than 7 mph any direction occur from 48 to 58 percent of the time depending on the month. Estimates at other speeds are presented in Figures 9 to 13. Calm is defined as wind of less than 1 mph.

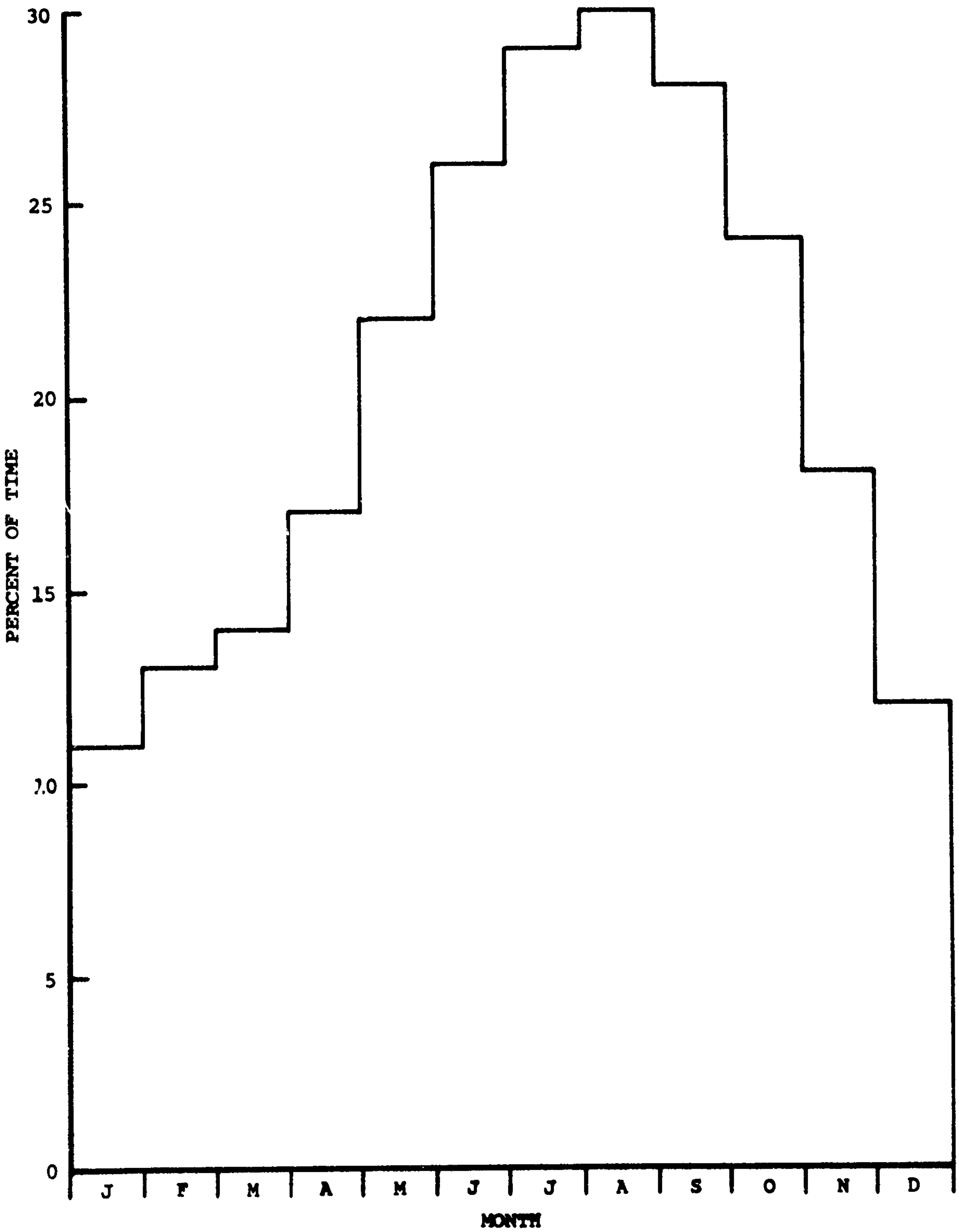


Figure 9. Estimated Prevalence of Calm at Dabob Bay Range
(Wind speed less than 1 mph)

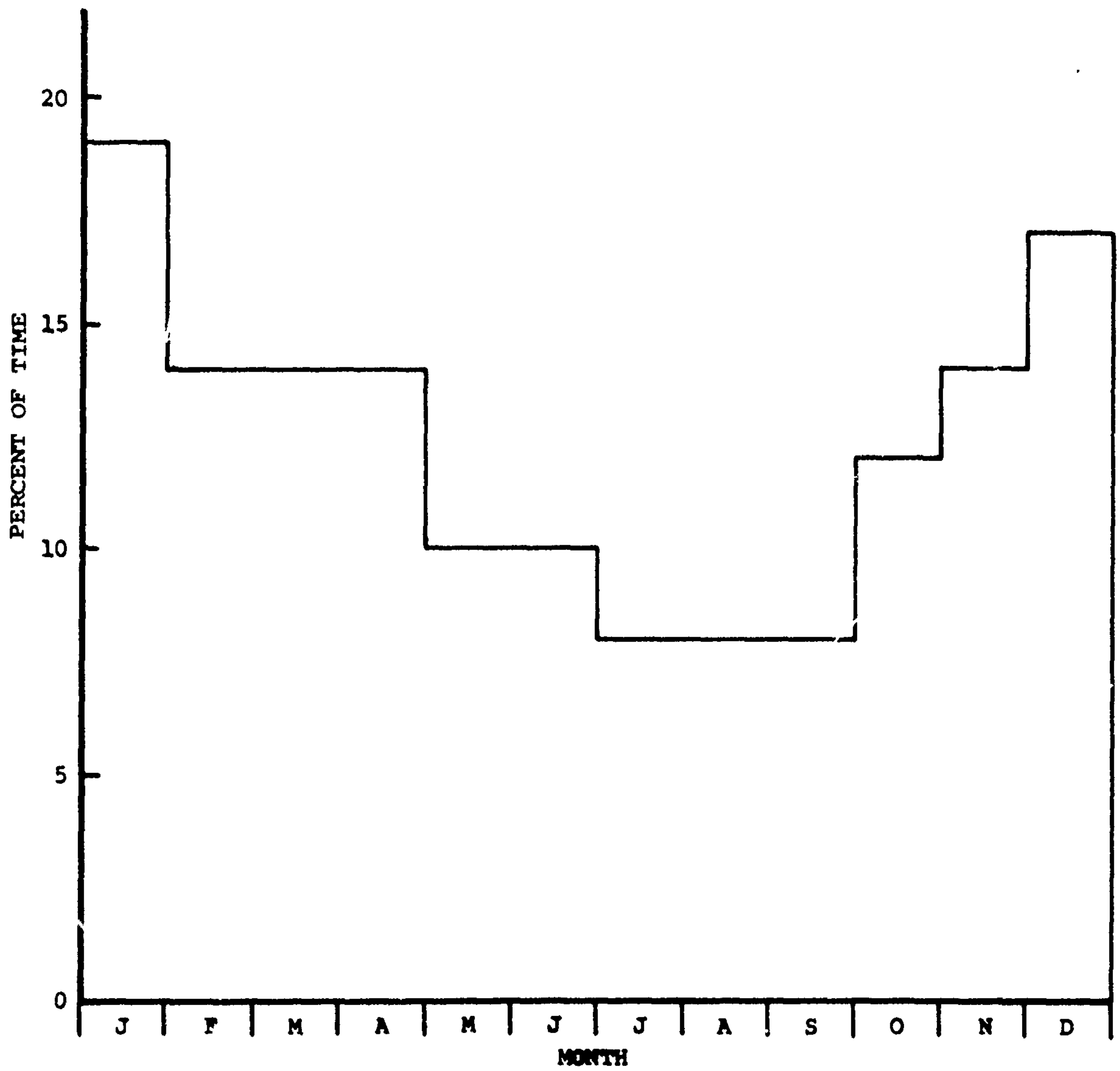


Figure 10. Estimated Prevalence of Southerly Wind Strength Exceeding 7 mph at Dabob Bay Range

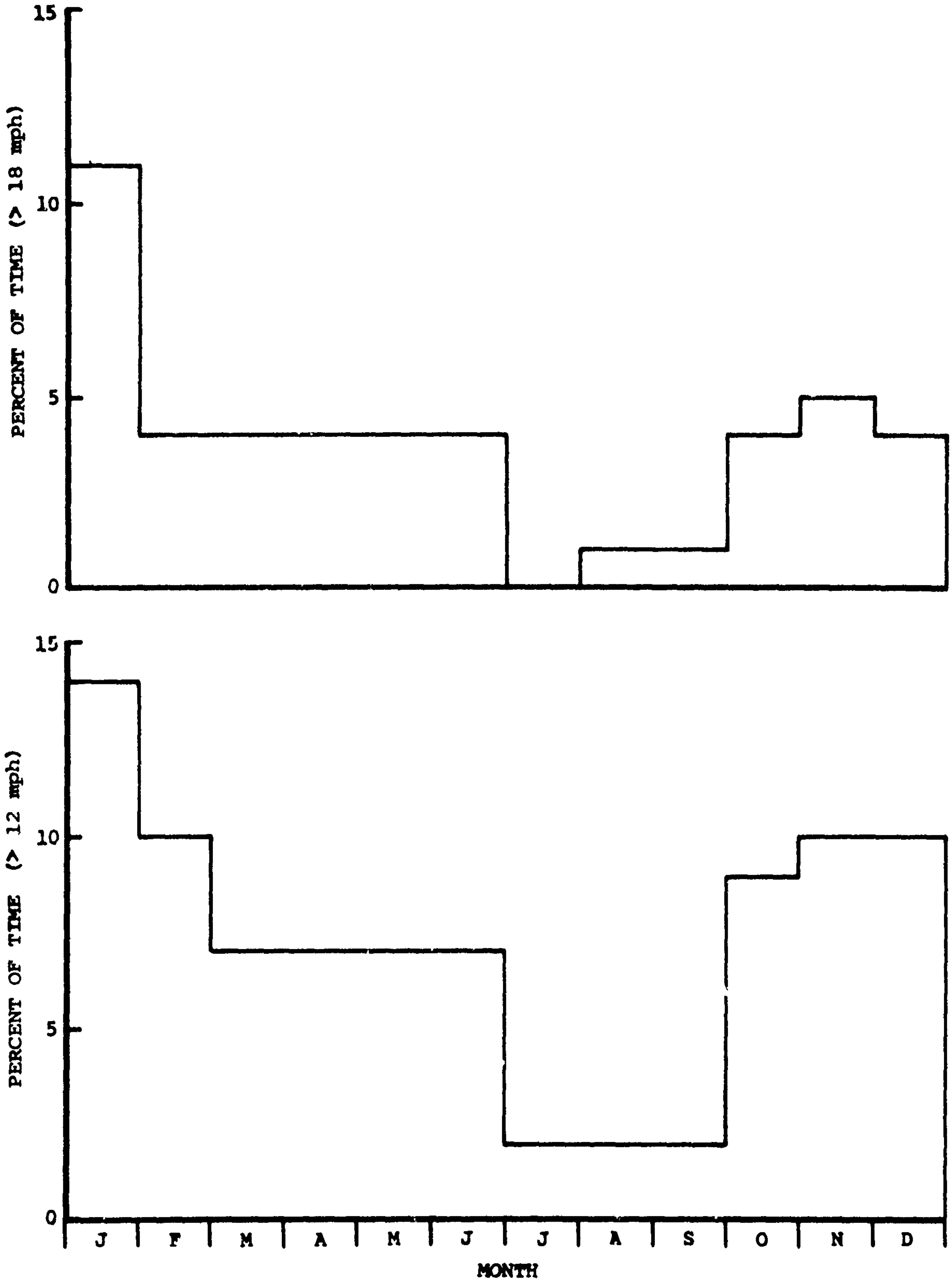


Figure 11. Estimated Prevalence of Southerly Wind Strength Exceeding 12 and 18 mph at Dabob Bay Range

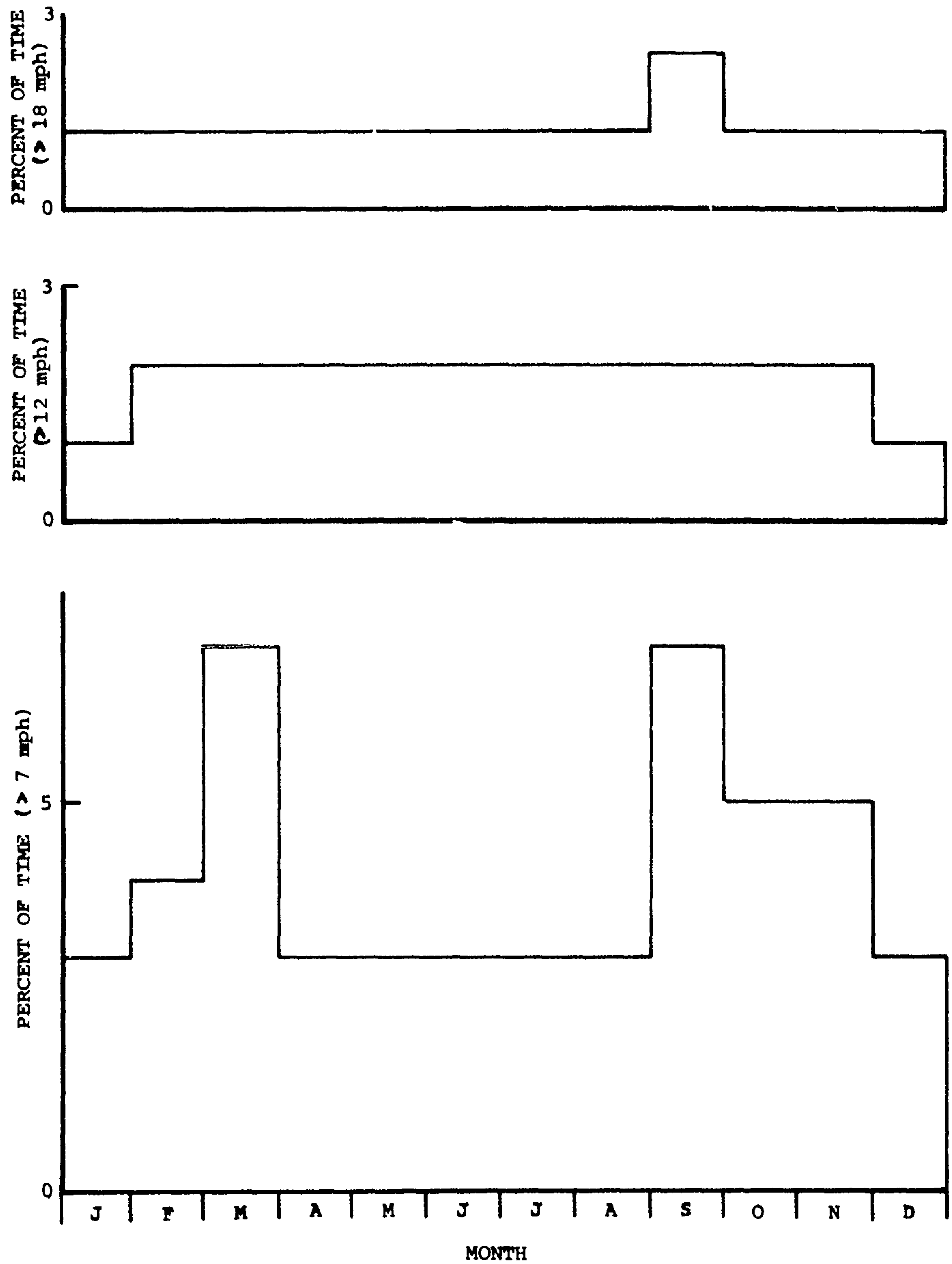


Figure 12. Estimated Prevalence of Northerly Wind Strength Exceeding 7, 12, and 18 mph at Dabob Bay Range

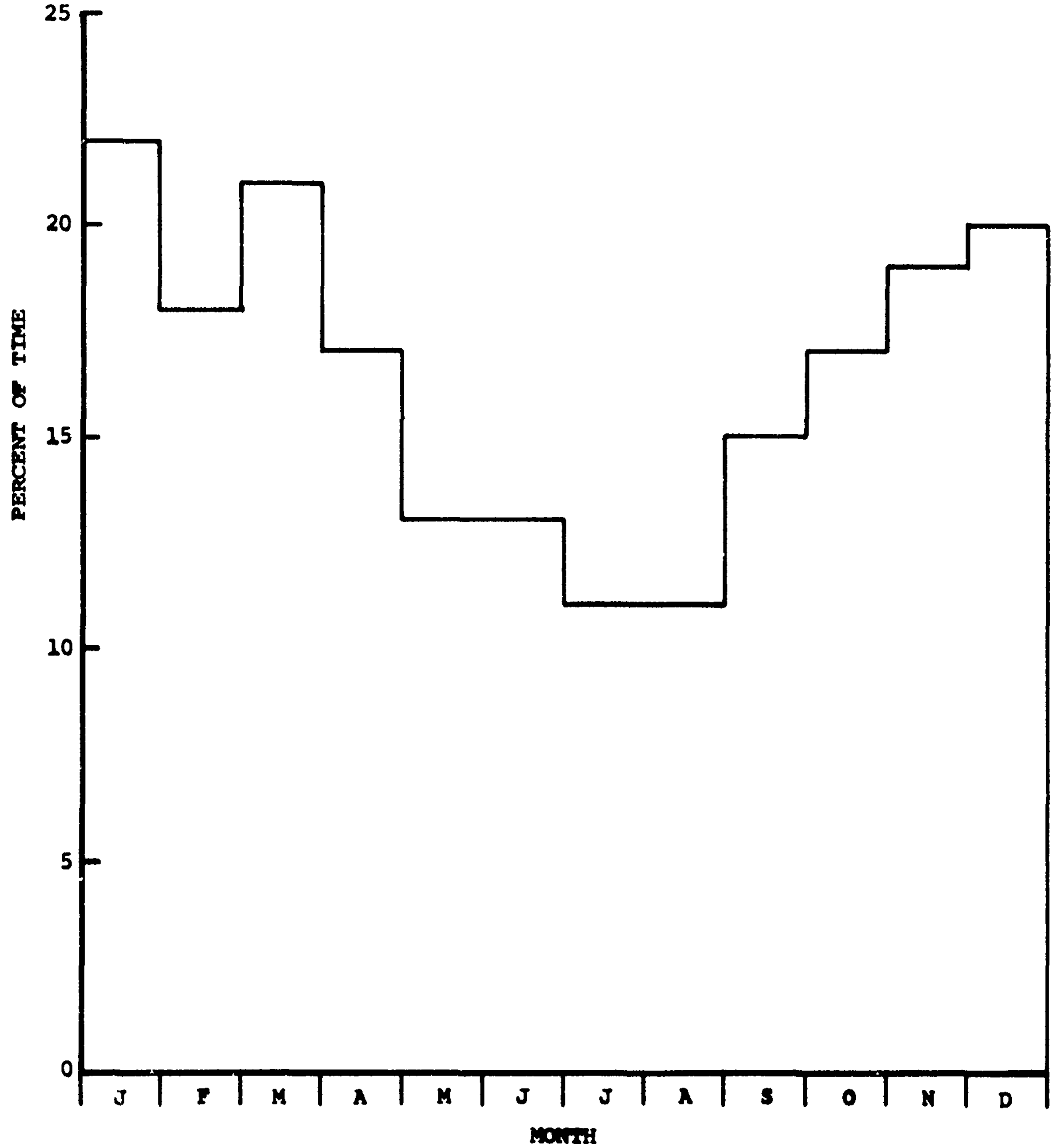


Figure 13. Estimated Prevalence of Northerly or Southerly Wind Strength Exceeding 7 mph at Dabob Bay Range

3. SOUND SPEED

A. INTRODUCTION

Sound speed is a function of temperature, depth (pressure), and salinity. In Dabob Bay the greatest variations in sound speed occur in the topmost 100-foot layer and are due to seasonal temperature and salinity changes.

At greater depths considerably smaller temperature variations also perturb sound speed. These latter temperature variations are cellular-type inhomogeneities. Their depth and location, measurements along the range centerline indicate, are unpredictable.

B. TYPICAL ENVELOPES

Because of the inhomogeneities the sound speed and temperature envelopes are necessarily broad, as only the coarsest of predictive envelopes is considered significant. Five predictive envelopes that describe the Dabob Bay seasonal sound speed characteristics are shown in Figure 14. These profile envelopes also indicate temperature characteristics at depths greater than 100 feet, where salinity variation is minimal.

Under constant salinity and depth-pressure conditions, the variation of sound speed with temperature amounts to around 9 ft/sec/°C. However, in Figure 14 the envelope abscissa scales are 25 ft/sec and 2°C for sound speed and temperature respectively, because of the computer plotting scales presently used. Sound speed variations due to salinity amount to around 4 ft/sec/‰* and must be accounted for in the topmost layer, where large seasonal changes in salinity occur. Depth/pressure has less effect on sound speed variations in Dabob. This is because a 600-foot depth increase causes only about a 10 ft/sec sound speed increase.

The probability of occurrence *(P(X))* of each sound speed envelope for a yearly period is shown in Figure 15, which relates the following historical profile characteristics:

1. Profile envelope 1 is most applicable/probable during December, January, February, and March.

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*‰ = parts per thousand (ppt)

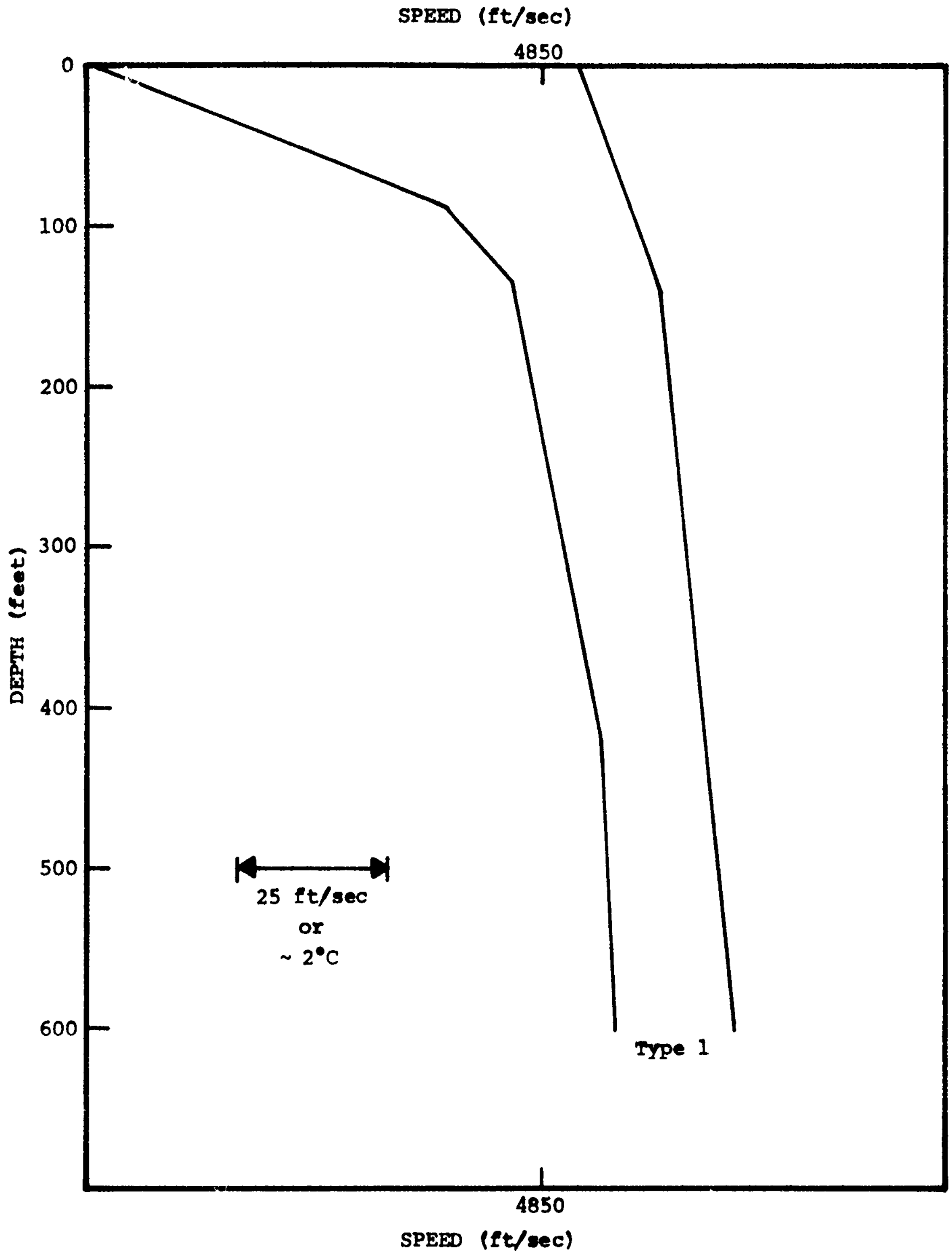

Figure 14. Sound Speed Profile Envelope Types (Page 1 of 5)
(For periods of prevalence, see Figure 15)

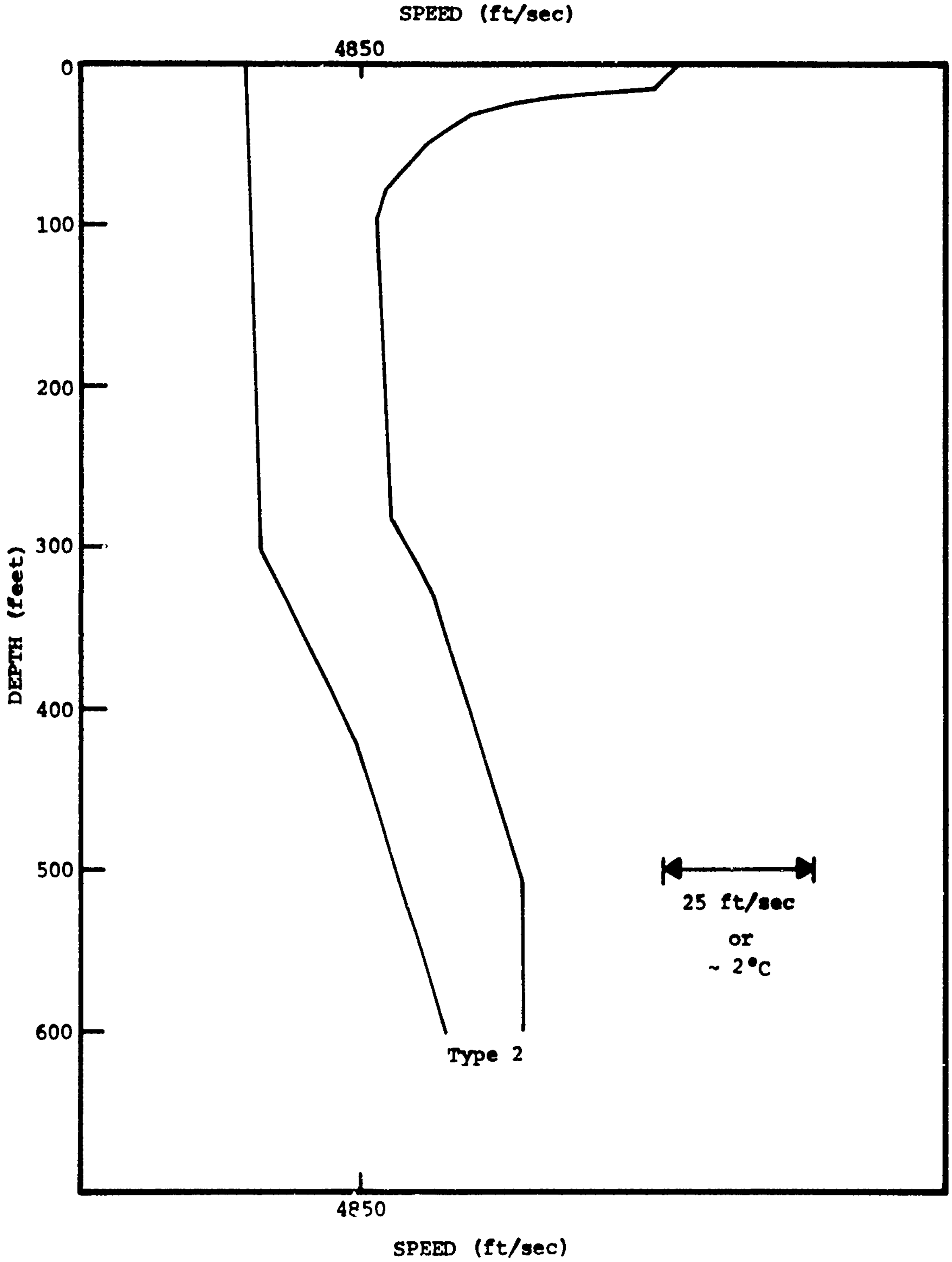

Figure 14. Sound Speed Profile Envelope Types (Page 2 of 5)
(For periods of prevalence, see Figure 15)

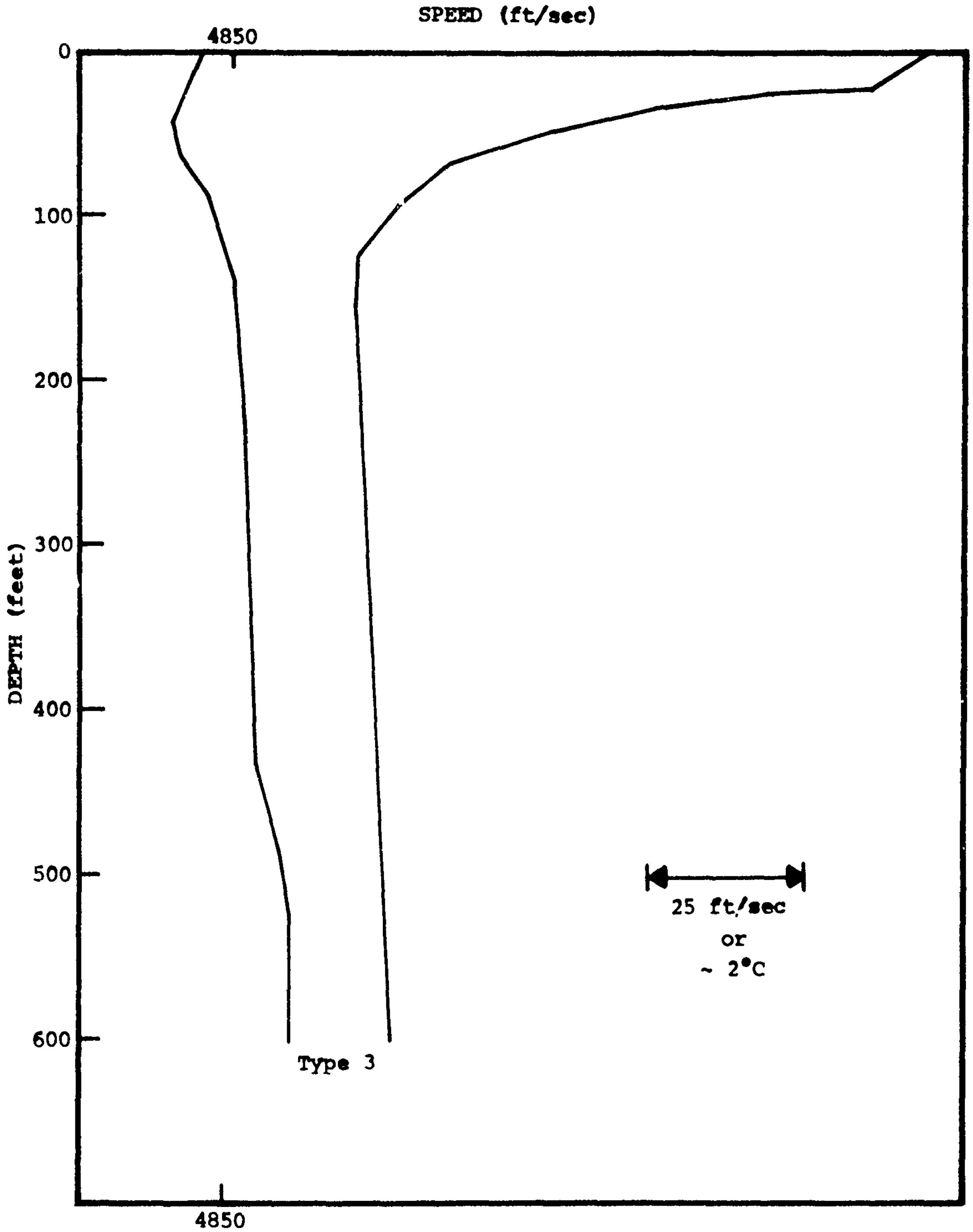

Figure 14. Sound Speed Profile Envelope Types (Page 3 of 5)
(For periods of prevalence, see Figure 15)

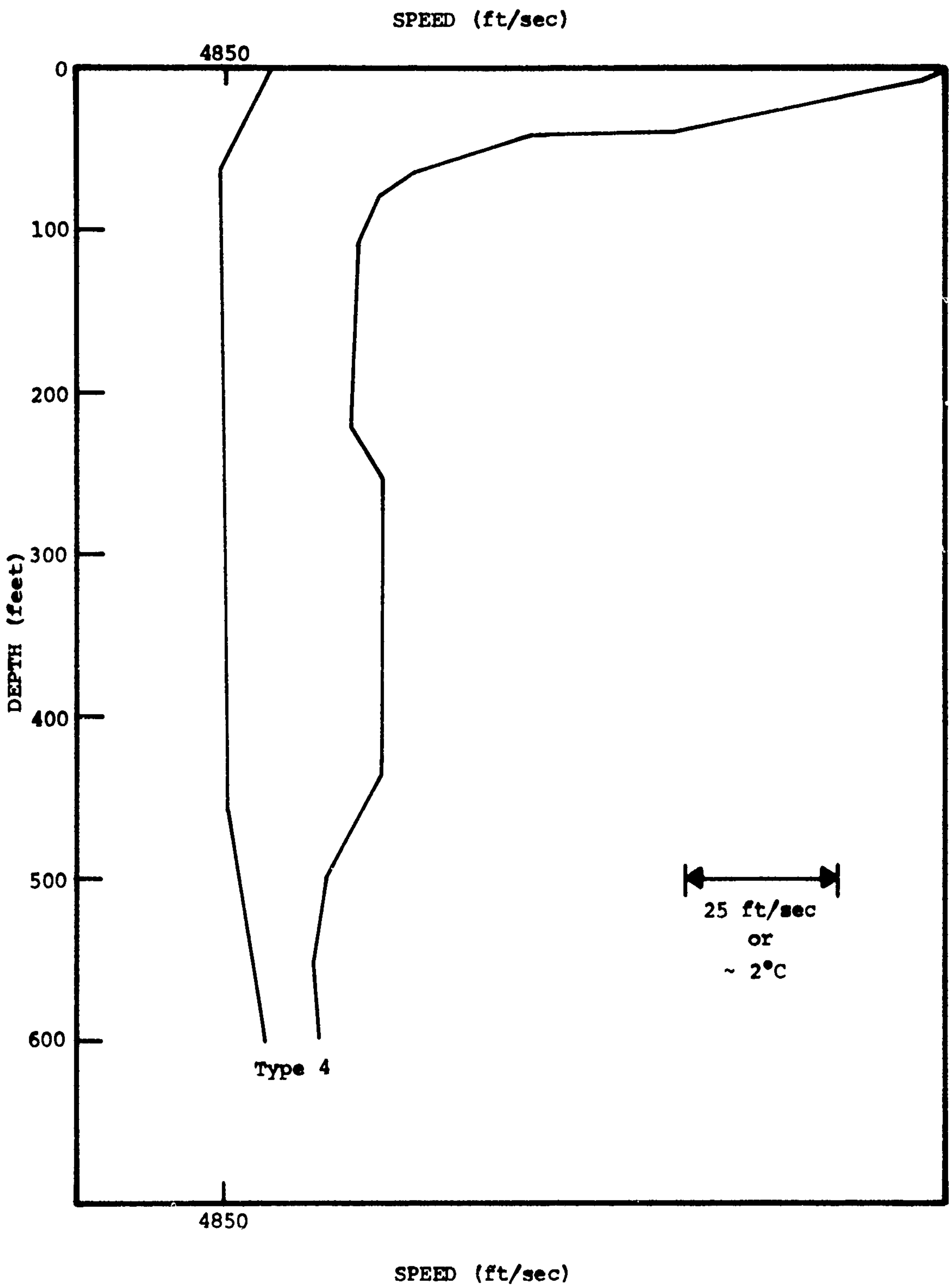

Figure 14. Sound Speed Profile Envelope Types (Page 4 of 5)
(For periods of prevalence, see Figure 15)

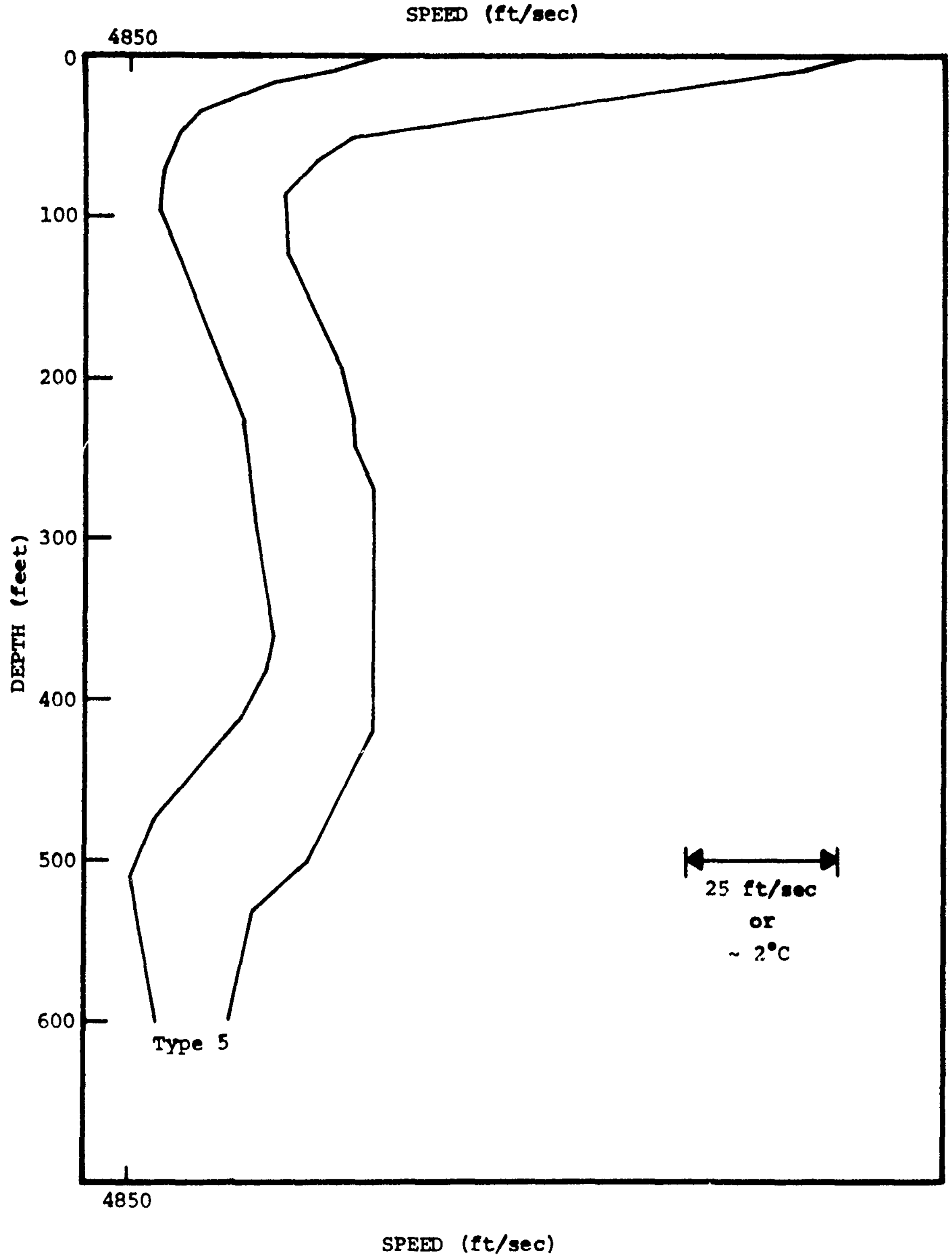

Figure 14. Sound Speed Profile Envelope Types (Page 5 of 5)
(For periods of prevalence, see Figure 15)

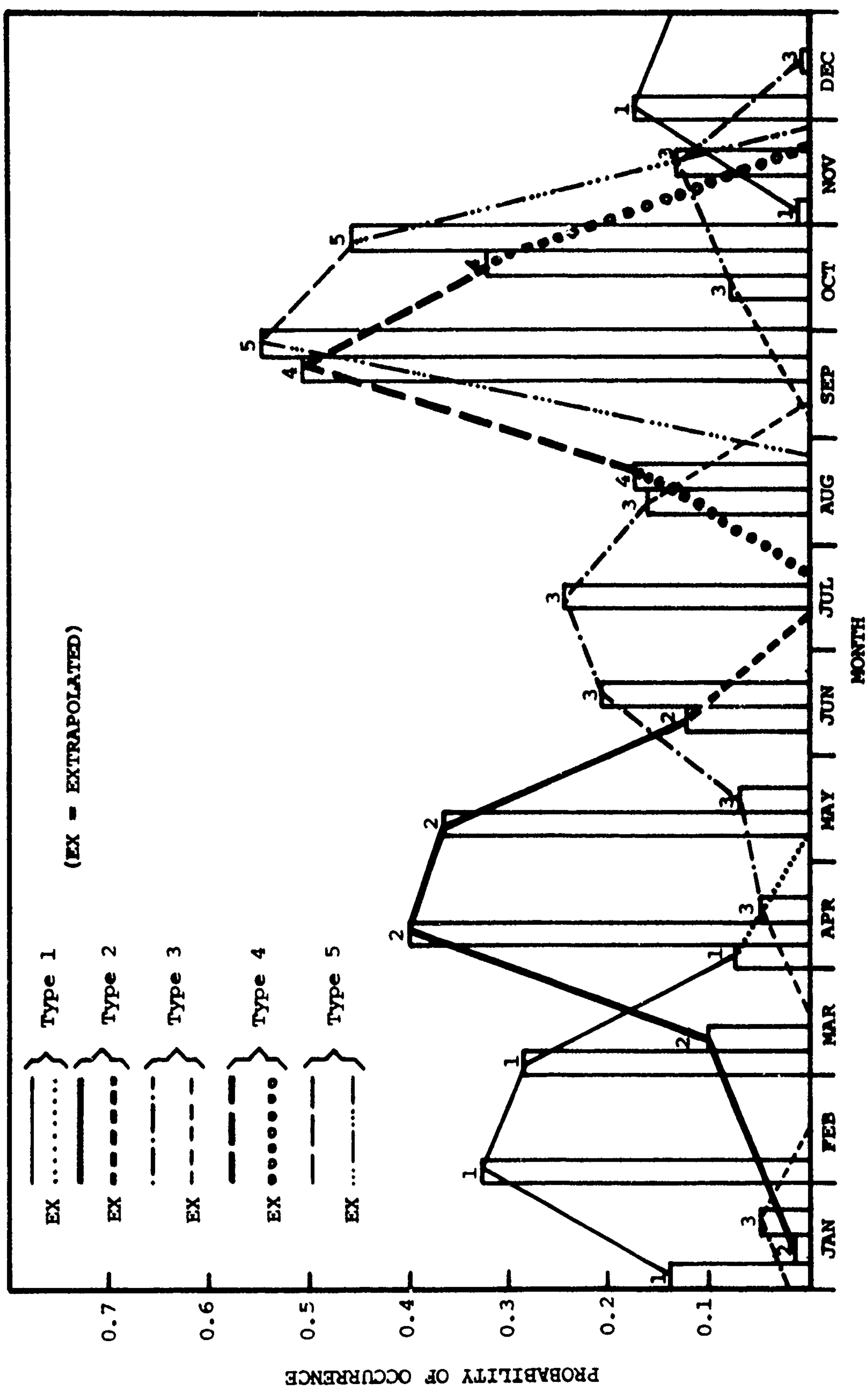

Figure 15. Probability of Occurrence for Each Profile Type

2. Profile envelope 2 is most applicable/probable during April and May and can also occur in late March and early June.

3. Profile envelope 3 is the most prevalent, season-wise, of all the profile envelope types. Although it predominantly occurs during June and July, this profile type could be observed during January, April, May, August, October, November, and even December.

4. Profile envelope 4 and profile envelope 5, which is a more "bowed" version of envelope 4, predominantly occur during September. Although profile envelope 4 has significant probabilities of occurrence in both August and October, profile 5 generally follows profile 4 and thus occurs in September and October only.

The five profile envelopes were adopted after an oceanographic data study spanning the years 1971 through 1975. Appendix A lists the data base for the sound speed/temperature and salinity profile envelopes of this report. A description of the instrumentation used to acquire these data is in NAVTORPSTA Report 1163[11]. Figure 16 illustrates the range centerline (℄) positional frequency of occurrence for the data samples listed in Appendix A.

C. SPATIAL VARIATIONS

When Hood Canal water enters Dabob Bay through wind or tidal action, a structure of water parcels is created. These parcels have different values of temperature and salinity than the most recent resident-type water in Dabob Bay. Ebbsmeyer's thesis found the parcels to have up to 100 feet of thickness and horizontal extents ranging up to several thousand feet. More important, however, was the finding that the large parcels remain recognizably intact for several weeks before they are dissipated by circulative processes.

The effect of these water parcels (temperature mainly and salinity discontinuities) is shown in Figure 17. This figure illustrates the tangle of sound speed profiles measured along the indicated range centerline positions during six days in October 1971.

To quantify the degree of tangle for predictive purposes, three roughness (R) scales were adopted: R > 5 ft/sec, R > 7.5 ft/sec and R > 10 ft/sec.

[11] NAVTORPSTA Report 1163, *Physical Oceanographic Characteristics of the Nanoose Range*, W. A. Middleton, January 1973, unclassified

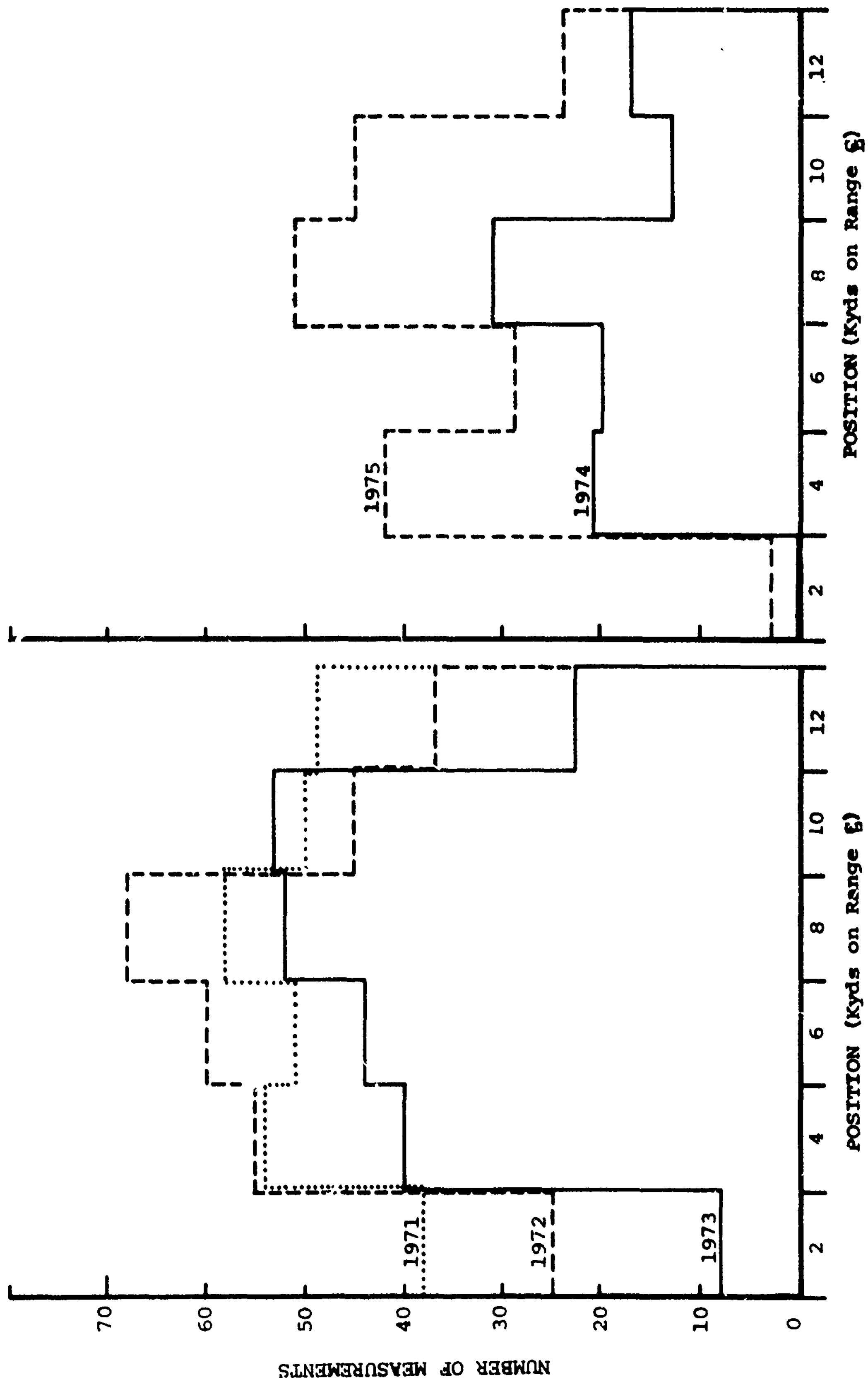

Figure 16. Sound Speed Profile Positional Distributions in Dabob Bay Range

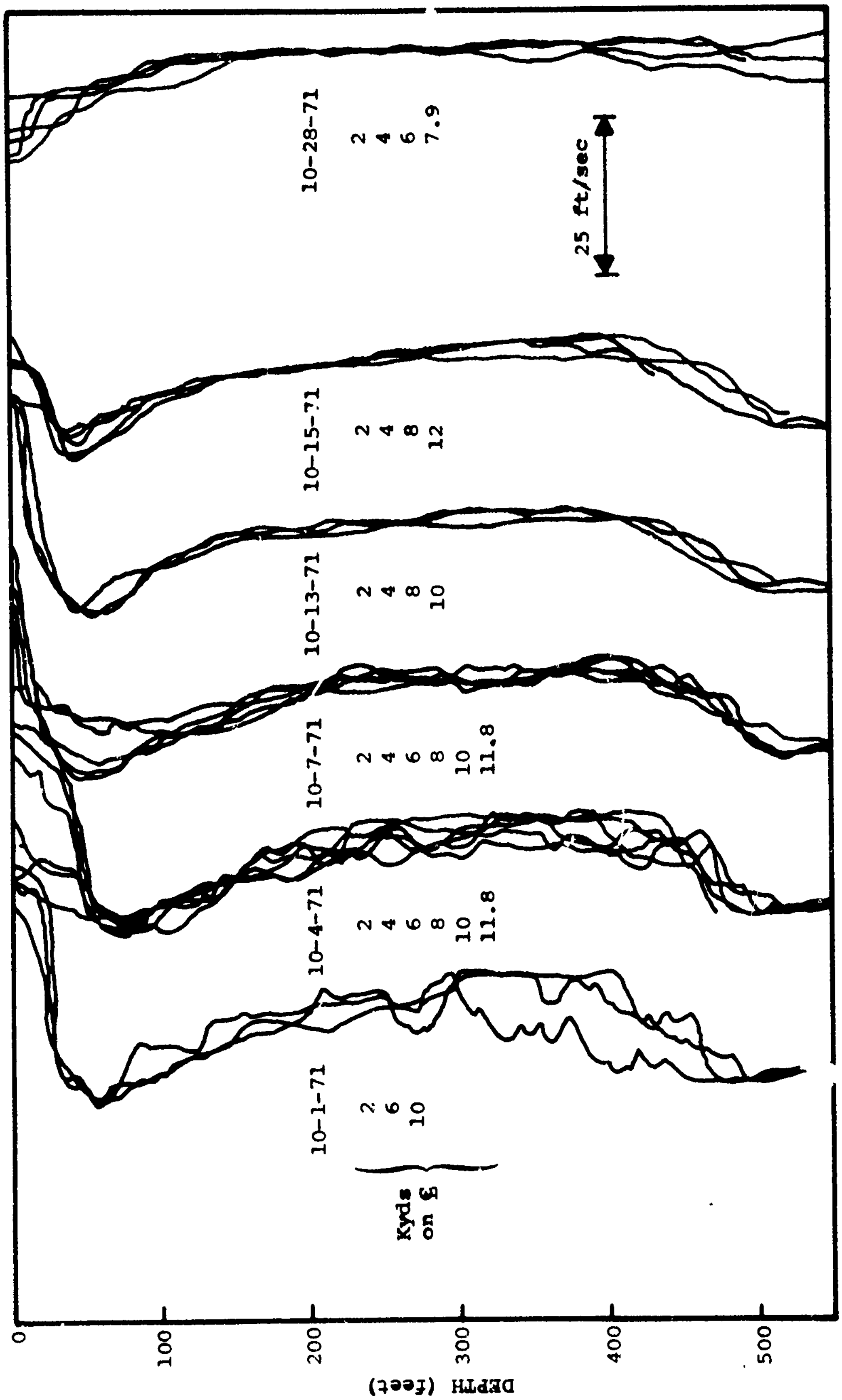

Figure 17. Temporal and Spatial Sound Speed Variations (Tangle)

The actual roughness is determined by the difference in measured sound speed between two or more spatially separated profiles for any stratum depths greater than 100 feet. Thus, surface layer patchiness created by topographic shadowing is excluded.

When the data base profiles of Appendix A are sorted on a daily basis, as in Figure 17, roughness can be predicted as in Figure 18. The figure shows that the spatial variation of sound speed profiles (roughness) is highest from July to September, lowest during November, moderately higher during March-April, and so on. This is useful information, showing, for instance, that tests sensitive to refraction anomalies should be planned for November or March-April.

The data supporting Figure 18 is shown in Appendix B. The asterisk (*) superscript indicates that the roughness scale was determined without benefit of available profile data in excess of 10.5 kyds along range centerline. Appendix B reveals the following seasonal and positional roughness trends:

1. In years such as 1971 and 1975 the yearly incidence of roughness scales of 10 and 7.5 is rather constant throughout the range.

2. Roughness is clearly higher near the mouth of the bay. This result is consistent with the known intrusion of Hood Canal water into the bay.

3. The incidence of spatial roughness on the scale of $R > 5$ is generally 40 percent or higher during most of the year and simultaneously highest for all three scales of roughness during August and September.

D. SALINITY

At depths shallower than 100 feet the climate forces large changes in the salinity structure as shown in Figure 19. Classification of the data samples of Appendix A revealed that at depths in excess of 130 feet, two 1-ppt (‰)-wide salinity profile envelopes could encompass all the data. At depths greater than 130 feet, the right profile envelope (Type 2) of Figure 19 is essentially the left profile envelope (Type 1) shifted over (increased salinity) by 1‰.

Although two profile envelopes define the deeper seasonal salinity changes, each envelope must necessarily accommodate more extreme surface layer variations. For example, the surface salinity can decrease to 24‰ or less during high precipitation and stream runoff periods.

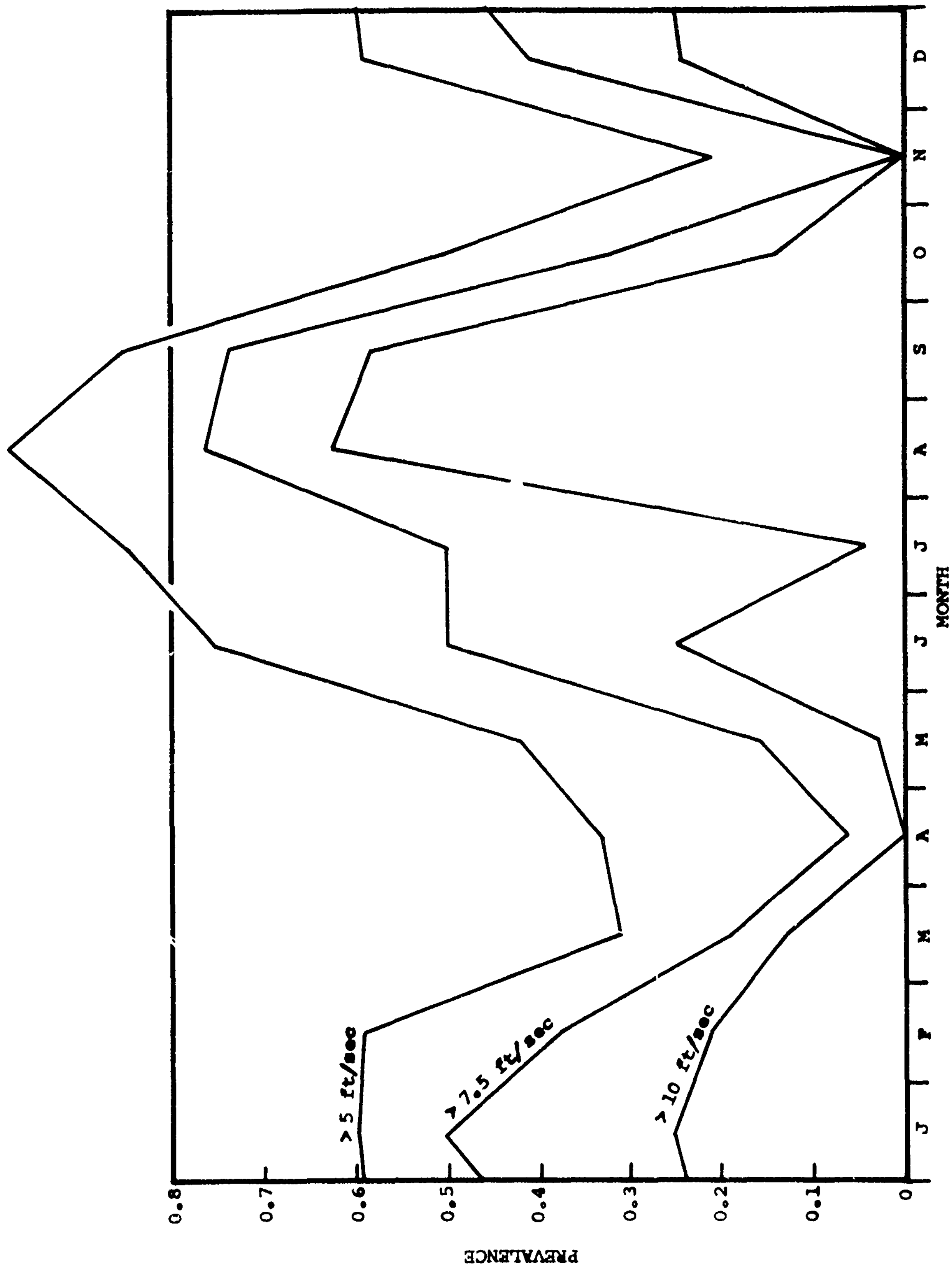

Figure 18. Monthly Incidence of Sound Speed Roughness

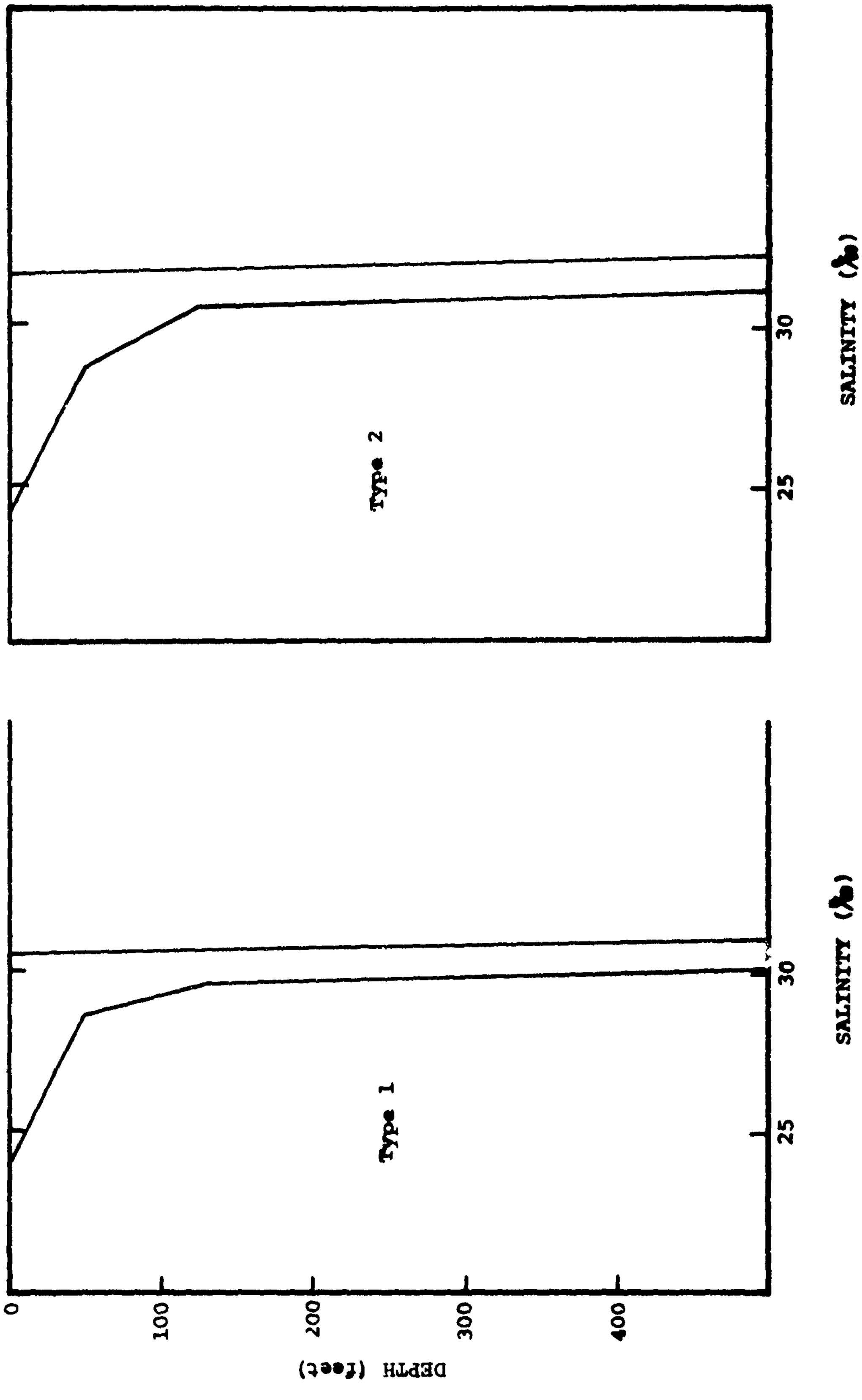

Figure 19. Dabob Bay Salinity Profile Envelopes

Appendix A data samples reveal the following salinity parameter characterizations:

1. Salinity profiles are generally similar along the range centerline from 2 kiloyards near the head of Dabob Bay to 12 kiloyards near the bay entrance.

2. At depths greater than 130 feet, the salinity typically varies between 29.5‰ and 32‰ over a yearly time frame.

3. Salinity generally monotonically increases with depth and helps provide a stable water column. However, temperature variations do occur in which the column becomes unstable (density wise) around September.

4. At depths greater than 130 feet the bay is generally less salinized in April through August than in September through March, as is indicated in the historical salinity profile envelope applicability plots of Figure 20. A single number in parenthesis implies that the profile is completely contained in either envelope Type 1 or 2. A "(1 & 2)" notation means that both envelopes are required to contain it.

The interpretation of Figure 20 is quite straightforward. Sometime during September or October of 1970, warmer, more salinized water from Hood Canal entered the bay and increased the salinity in a stable manner, (greater density water, etc.). Thereafter, winter and spring season fresh-water intrusions decreased the topmost layer salinity and established a positive halocline (salinity gradient). Mixing of deeper water with the less salinized surface layer subsequently reduced the overall salinity. This process continued through 1971 and most of 1972 as, apparently, no flushing of the bay occurred during 1971. In contrast a flushing or intrusion of more salinized Hood Canal water apparently did occur during 1972, 1973, and 1974.

A discussion of flushing is provided in the Kollmeyer thesis and the Ebbesmeyer thesis; the measured Hood Canal salinity is listed in Table 4; and profile envelope types are provided in Figure 21. The appearance of significantly more highly salinized water during late September through early December, indicated by the available data samples, is indicative of a yearly flushing potential in Dabob Bay.

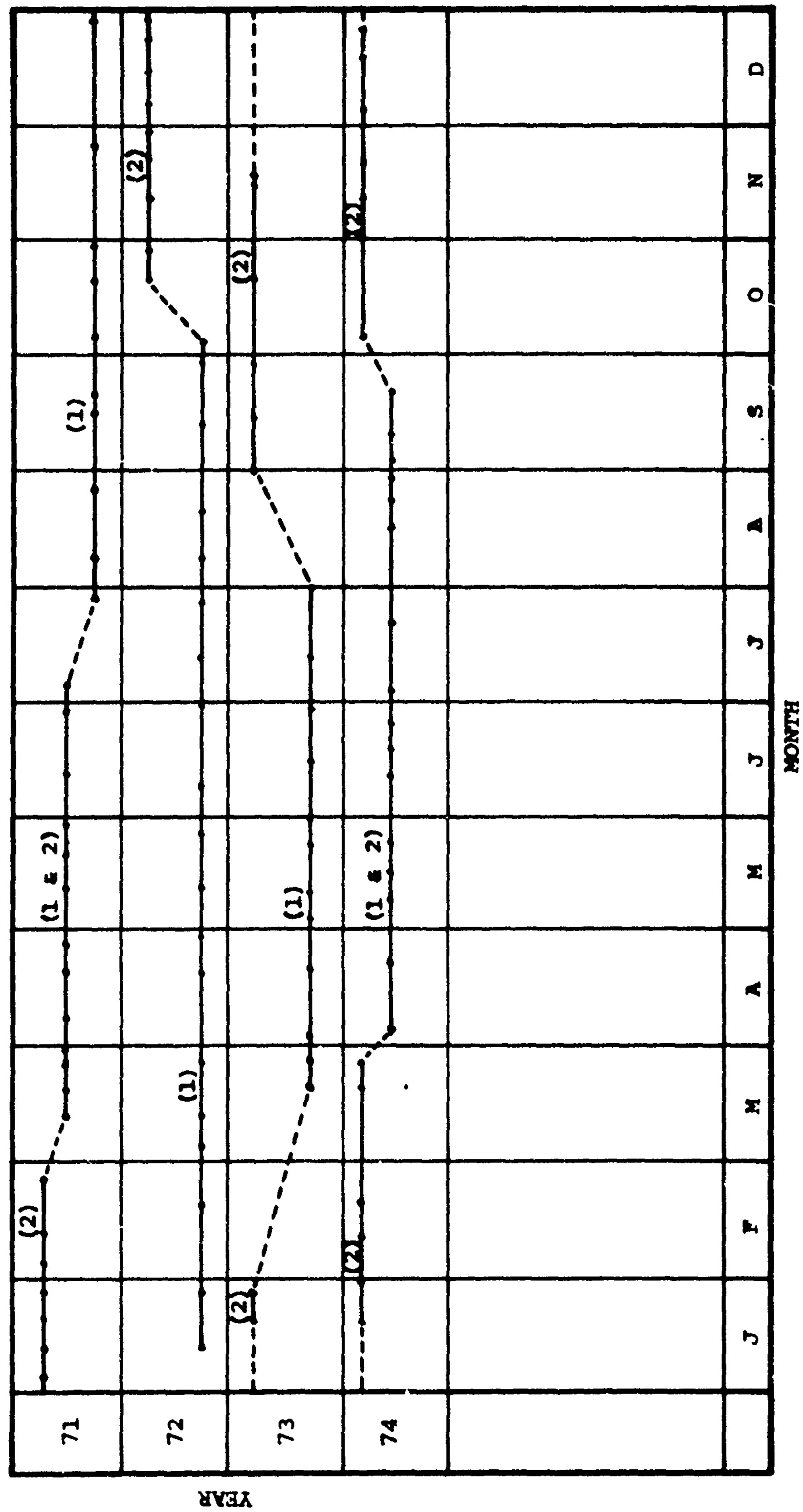

Figure 20. Occurrence of Salinity Profile Types
(For description of types see Figure 19)

Table 4. Hood Canal Salinity Data
(Source: WSAT Sonar Buoy)

Date	Salinity Envelope Types* Type A	Type B
Jan 26 1970	✓	
Feb 2	✓	
Feb 4	✓	
Nov 19		✓
Feb 12 1971	✓	
Feb 25	✓	
Mar 24	✓	
May 10	✓	
Sep 29		✓
Jan 13 1972	✓	
Feb 11	✓	
Jul 28	✓	
Sep 8	✓	
Jan 11 1973	✓	
May 15	✓	
May 22	✓	
Dec 5		✓
Mar 14 1974	✓	
Mar 21	✓	
Apr 9	✓	
Apr 22	✓	
May 16	✓	
Jun 14	✓	
Jun 17	✓	
Jun 26	✓	
Jul 2	✓	
Jul 11	✓	
Jul 23	✓	
Aug 5	✓	
Aug 23	✓	
Nov 7		✓
Jan 30 1975	✓	
Apr 2	✓	
Jun 9	✓	
Jun 17	✓	
Jul 14	✓	
Aug 8	✓	
Jan 28 1976	✓	

**See Figure 21.*

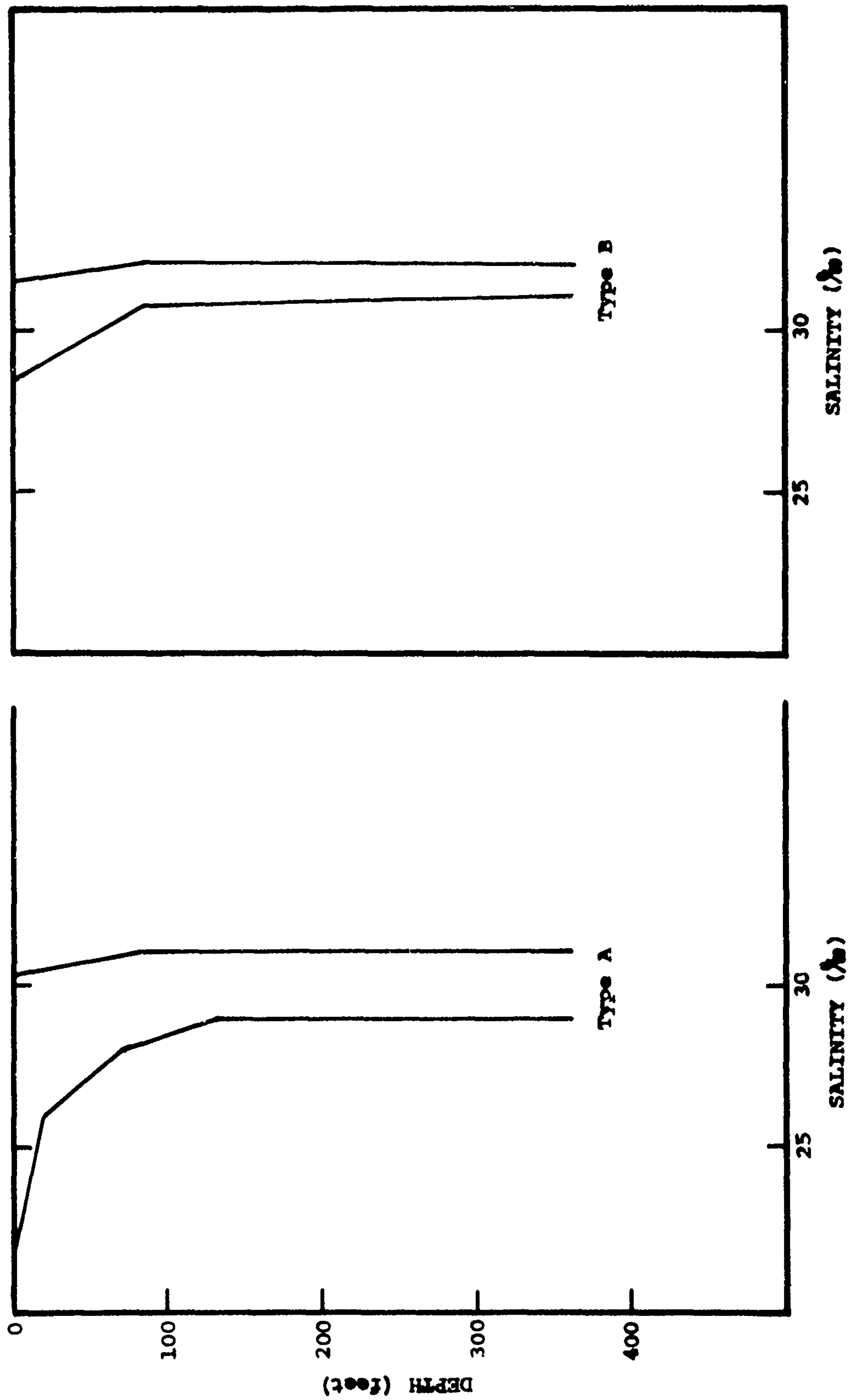

Figure 21. Hood Canal Salinity Profile Envelope Types

4. ACOUSTICS

Dabob Bay is acoustically complex whenever the transmission path between two points is nearly horizontal or entails one or more reflections from the bottom. Short-pulse or long-pulse CW apparatus testing entails several complexities due to reverberation, refraction, and multipath transmission.

Although the bay is suitable for accurate acoustic tracking endeavors it proves itself resistant to many types of operations and to tests of devices where acoustic operation is altered by volume and bottom reverberation and/or pervasive refraction conditions.

Discussion of the complexities will be approached as follows: First, all the water will be removed so the basin shape, geological characteristics, and present estimated covering can be examined. After this the water will be returned and its refractive characteristics illustrated. Next, the known inhomogeneities conducive to volume scattering will be examined. Lastly, surface and bottom reverberation, estimated transmission loss characteristics, and ambient noise will be summarized.

A. GEOLOGICAL FACTORS

Formation of the Dabob Bay basin is attributed by Gilliland[12] to glacial sculpturing of pre-existing rock. Glaciation ended some 18,000 years ago upon completion of the Vashon stage, per Shannon and Wilson[13]. This stage, preceded by earlier glacial epochs, laid down a complex sequence of glacial and interglacial deposits over the volcanic bedrock. Near-surface sediment deposits on the Kitsap, Toandos, and Bolton peninsulas and other lowland areas including the west side of Dabob Bay and Hood Canal stem from the Vashon stage of the Fraser glaciation. However, there are several exposures of volcanic rock, such as at Pulali point and the tip of Bolton peninsula.

Figure 22 shows the location of all the aforementioned peninsulas, lowlands areas, the three major sills, and streams/rivers capable of providing eroded sediment for the Dabob basin.

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[12] APL/UW/TE/60-10, *Reconnaissance Geology of the Dabob Bay Area*, John H. Gilliland, Applied Physics Laboratory, University of Washington, Seattle, WA, 17 June 1960, unclassified

[13] File No. W-2537-05, *Subsurface Investigatio Trident Support Complex Bangor Annex, WA*, Shannon and Wilson, Inc., Geotechnical Consultants, Seattle, WA, October 23, 1973, unclassified

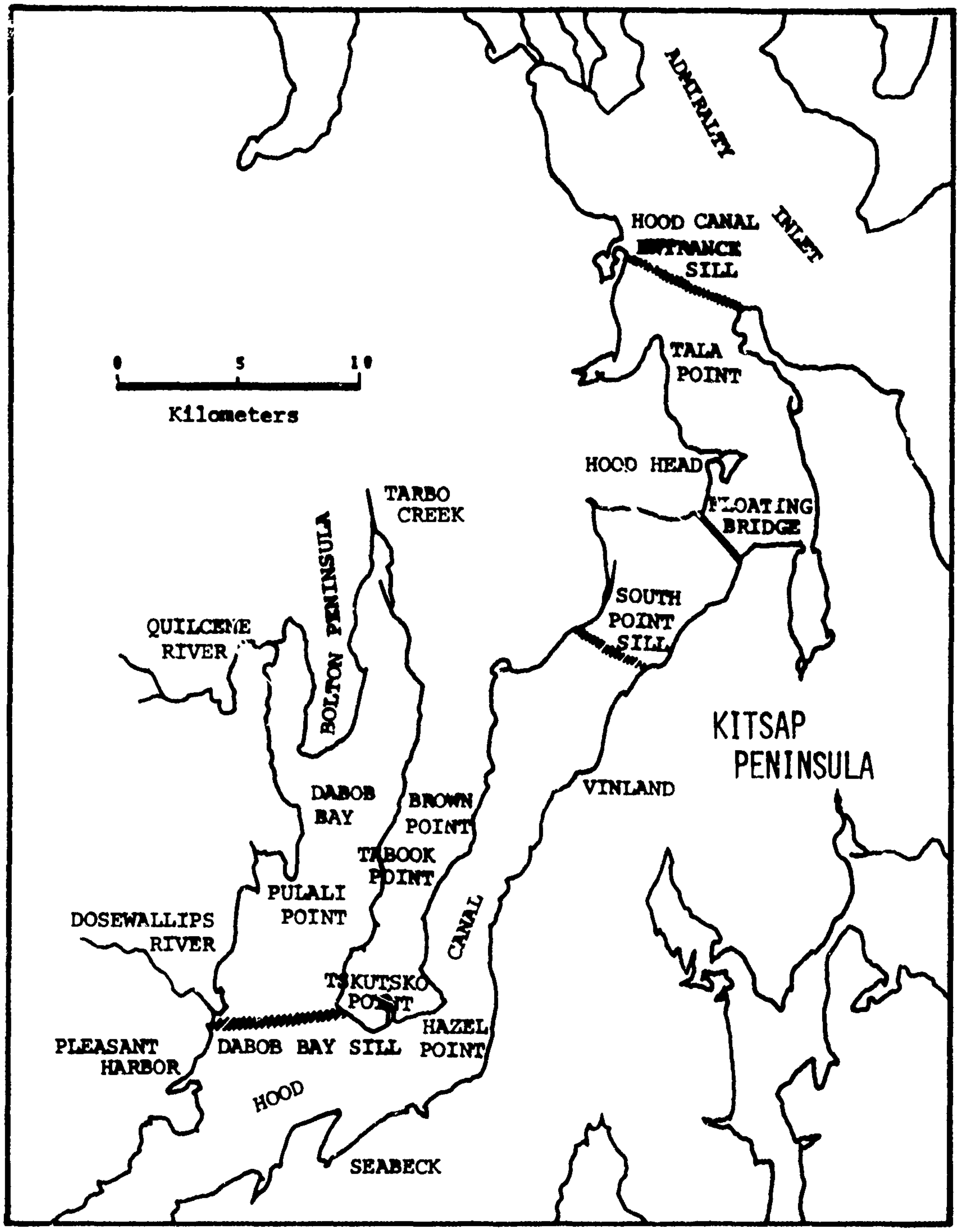

Figure 22. Dabob Bay, Hood Canal, and Major Sills

Figure 23 illustrates the acoustic range areal extent within the Dabob basin and the location of the selected cross sections shown in Figures 24 through 29. These sections were determined from hydrographic survey charts H9035 and H9038. To be noted in these cross sections is the steep slope of the eastern boundary of the basin. Slopes of these magnitudes and less are subject to retrogressive slumping (sand slides) per Andresen and Bjerrum[14]. This mechanism is proposed for explaining the presence of sand at or near the bottom as well as along the basin slopes.

From extensive surficial and boring samples obtained on the Kitsap peninsula side of Hood Canal for Trident-related work, the sedimentary conditions in the Dabob basin can be safely inferred. Studies show that recent sedimentation covers the submerged glacial deposit sublayers. In particular the field sampling work of Burns[15], Linger[16], and Wang[17] in Dabob Bay and Hood Canal correlate with surface samples acquired along the Trident/Bangor waterfront for preparation of an impact statement.

Figure 30 shows the locations where the bottom (subsurface) samples were obtained. A Shipek model 860 sediment sampler was used. This device acquires a layer of sediment approximately four inches deep in the center and 0.43 square-foot in surface area. The size distribution (by weight) analysis is presented in Table 5 for the samples. Figure 30 and Table 5 are taken from *Trident Environmental Baseline Study Interim Report*[18].

The size-distribution analysis of Table 5 illustrates on a general basis that as the water depth increases the percentage of fine-sediment constituents (clay-silt, fine sand) also increases. This progression is of course due to the settling out of coarse particles closer to shore in generally shallower water and to the seaward removal of fine sediment constituents through wave turbulence, leaving the coarser and heavier sediment particles behind. Burns' thesis provides a good summary descrip-

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[14] *Slides in Subaqueous Slopes in Loose Sand and Silt*, A. Andresen and L. Bjerrum, Marine Geotechnique, University of Illinois Press, Urbana, 1967, unclassified

[15] *A Model of Sedimentation in Small Sill-less Embayed Estuaries of the Pacific Northwest*, Robert E. Burns, Ph.D. Thesis, University of Washington, Seattle, WA, 1962 unclassified

[16] NAVTORPSTA Dwg 15121, *Iso-Firmness Contours - Dabob Bay*, (data from E.R. Linger), June 1960, unclassified

[17] *Recent Sediments in Puget Sound and Portions of Washington Sound and Lake Washington*, F. H. Wang, Ph.D. Thesis, University of Washington, Seattle, WA, 1955, unclassified

[18] *Trident Environmental Baseline Study Interim Report*, Naval Civil Engineering Laboratory, Port Hueneme, CA, June-September 1973, Vol. 3, unclassified

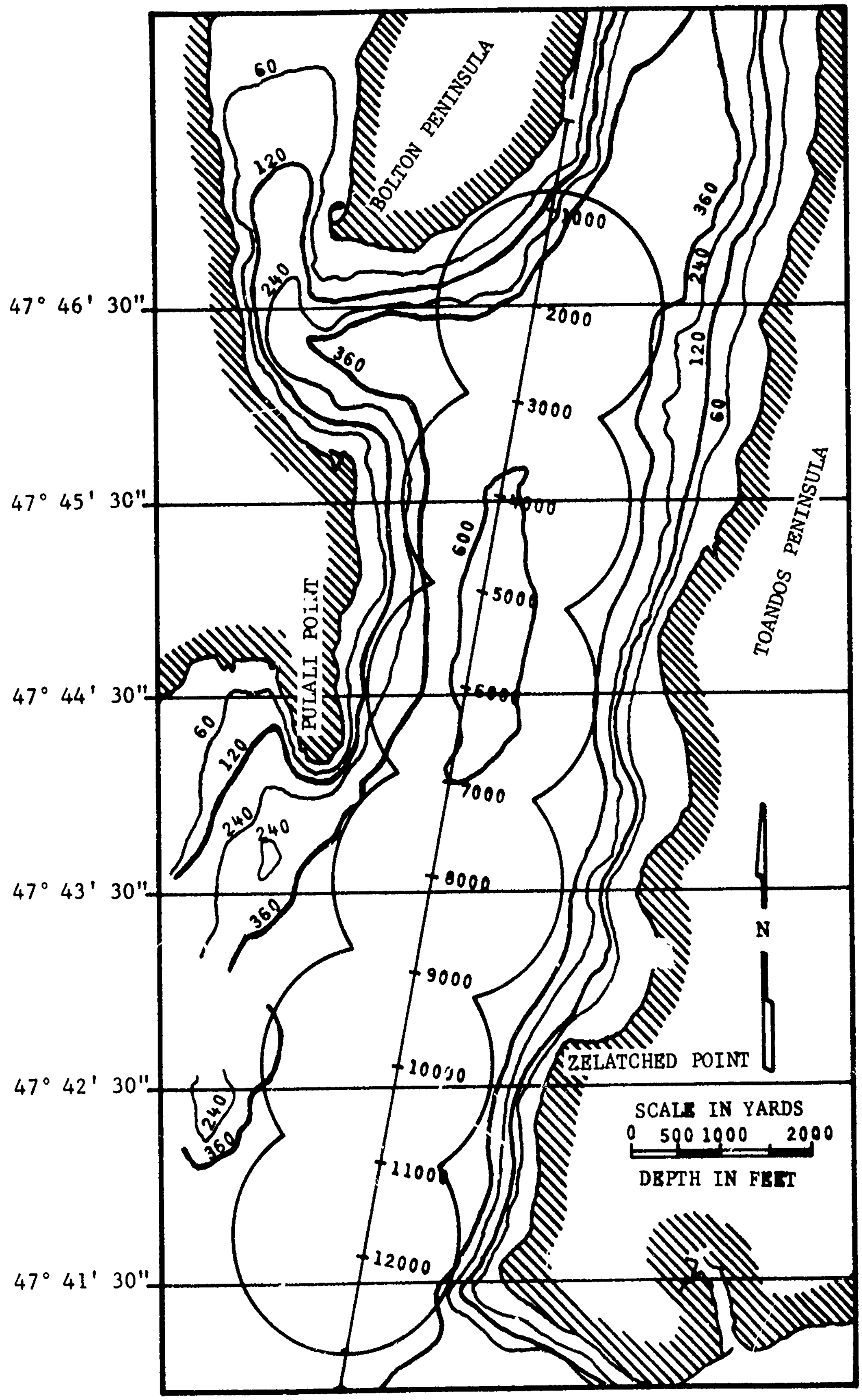

Figure 23. Locations of Transects Detailed in Figures 24 through 29

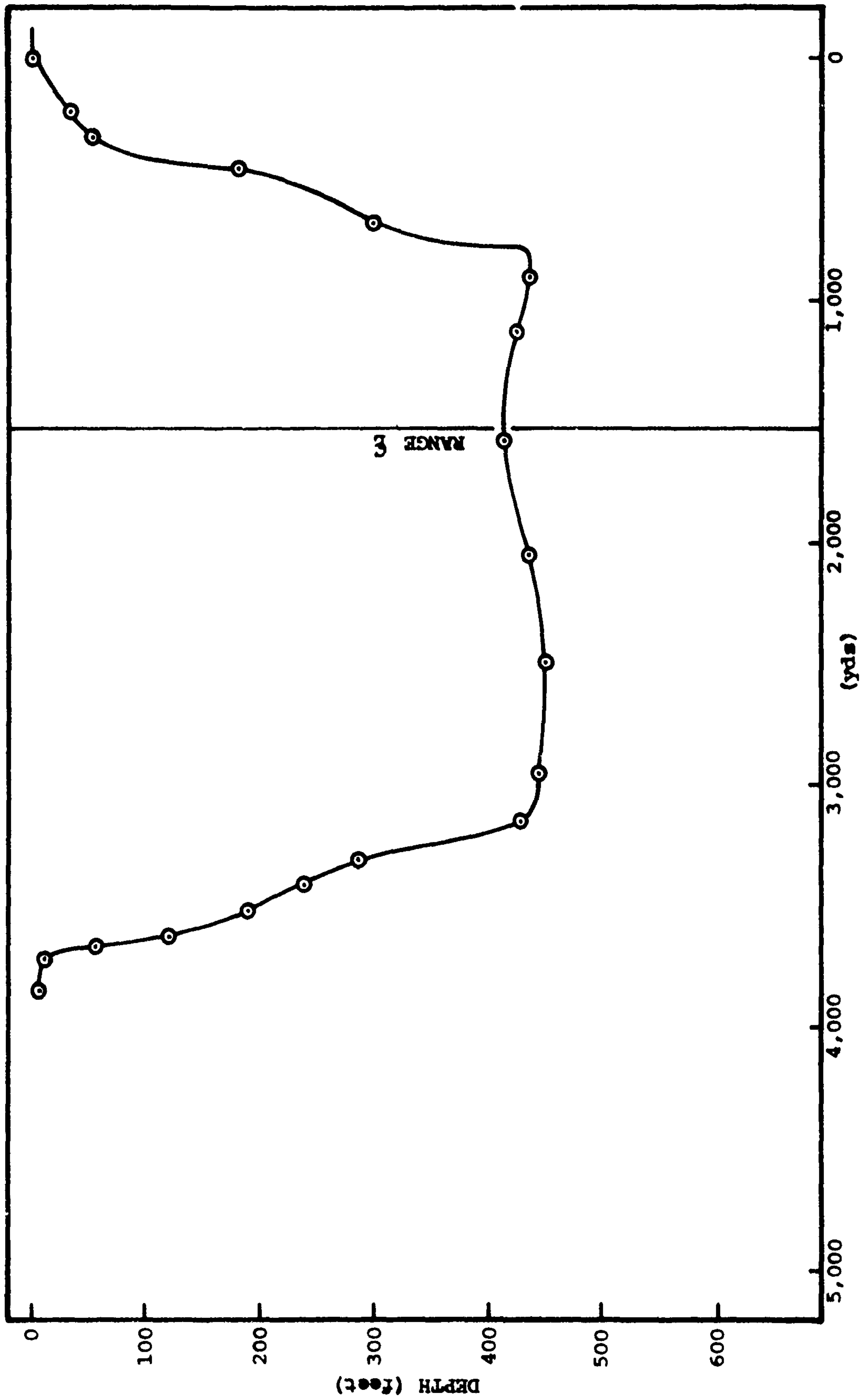

Figure 24. Dabob Basin Contour at Latitude 47°41'30" Vertical Exaggeration 15X

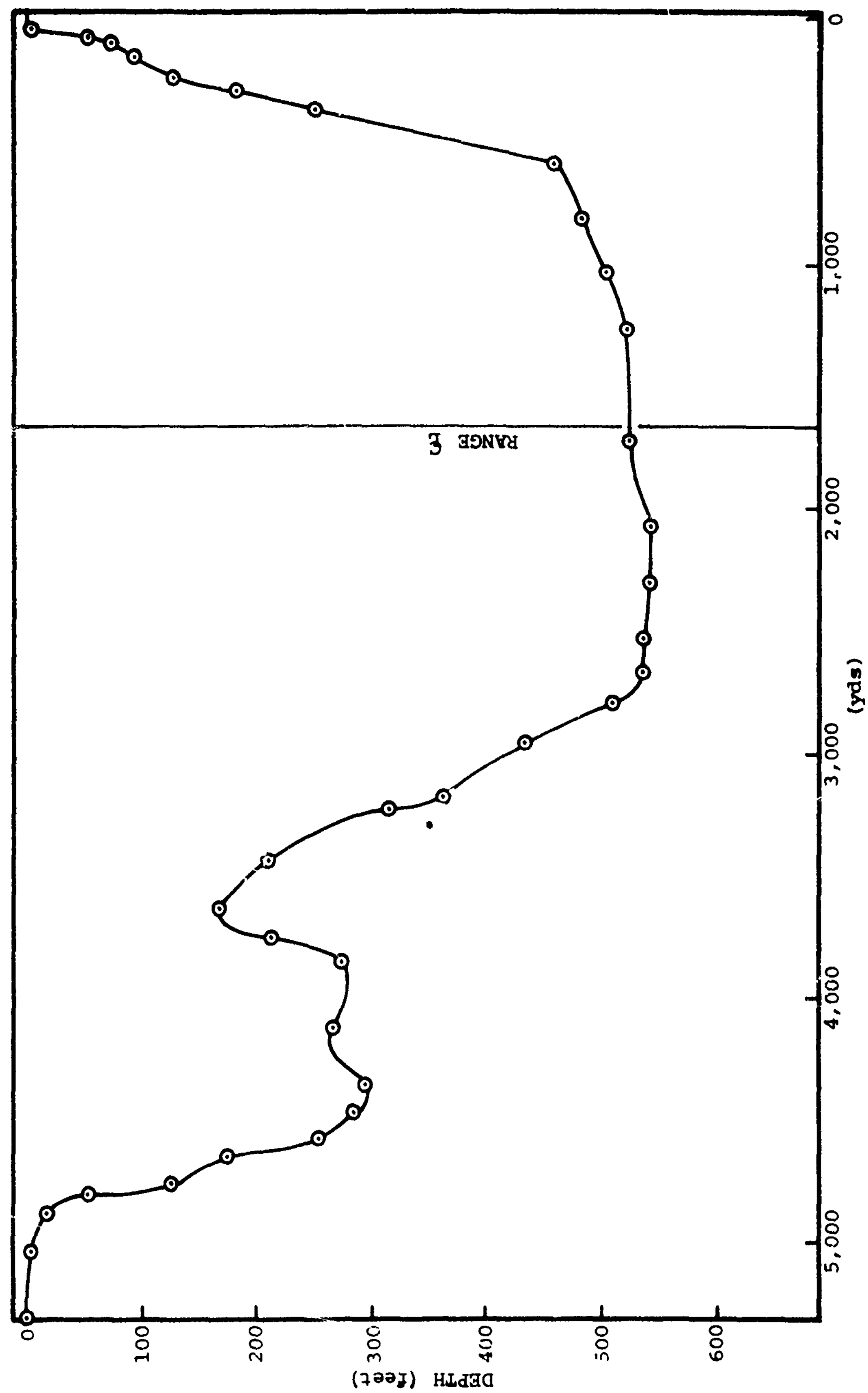

Figure 25. Dabob Basin Contour at Latitude 47°42'30" Vertical Exaggeration 15X

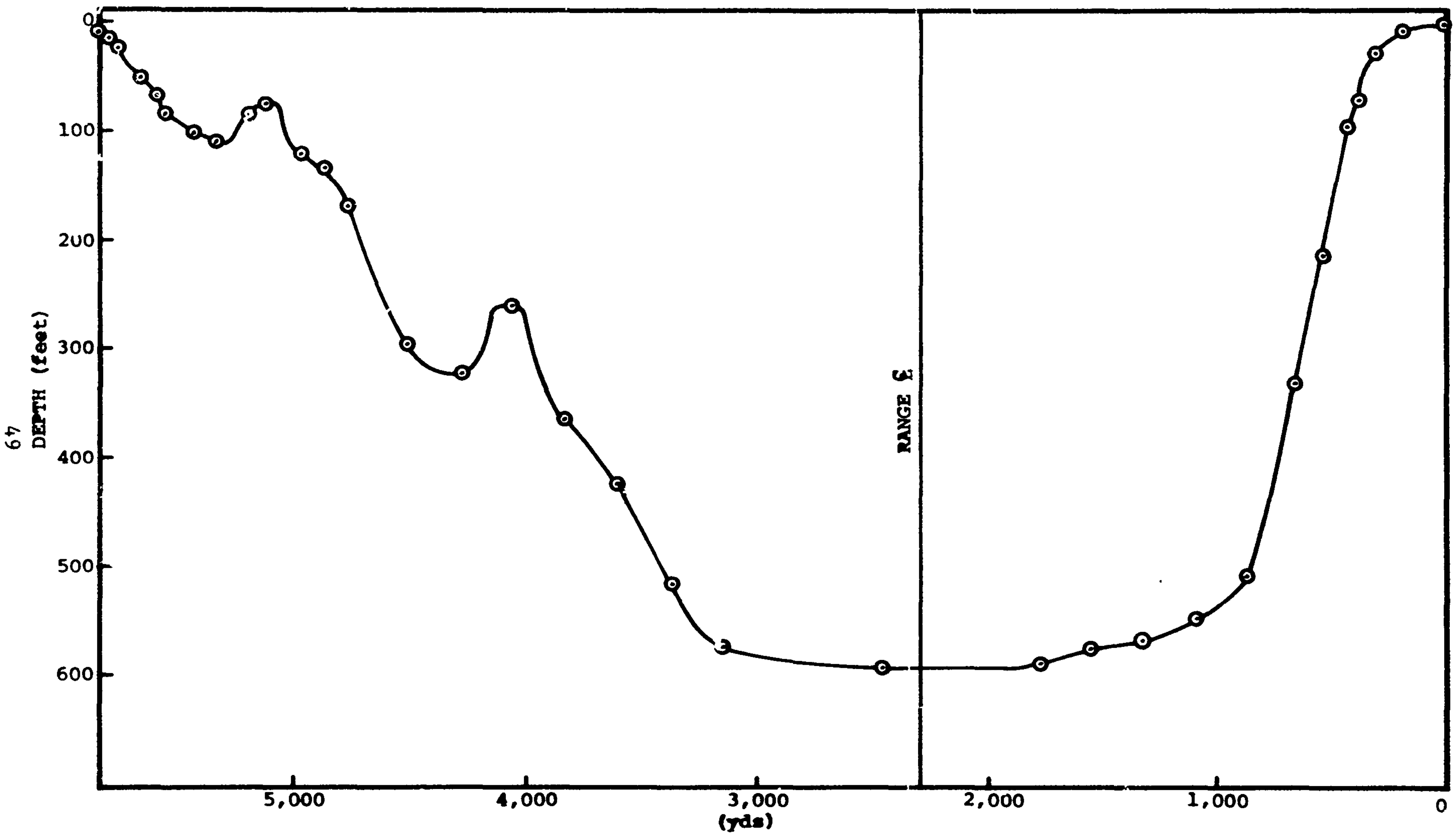

Figure 26. Dabob Basin Contour at Latitude 47°43'30" Vertical Exaggeration 15X

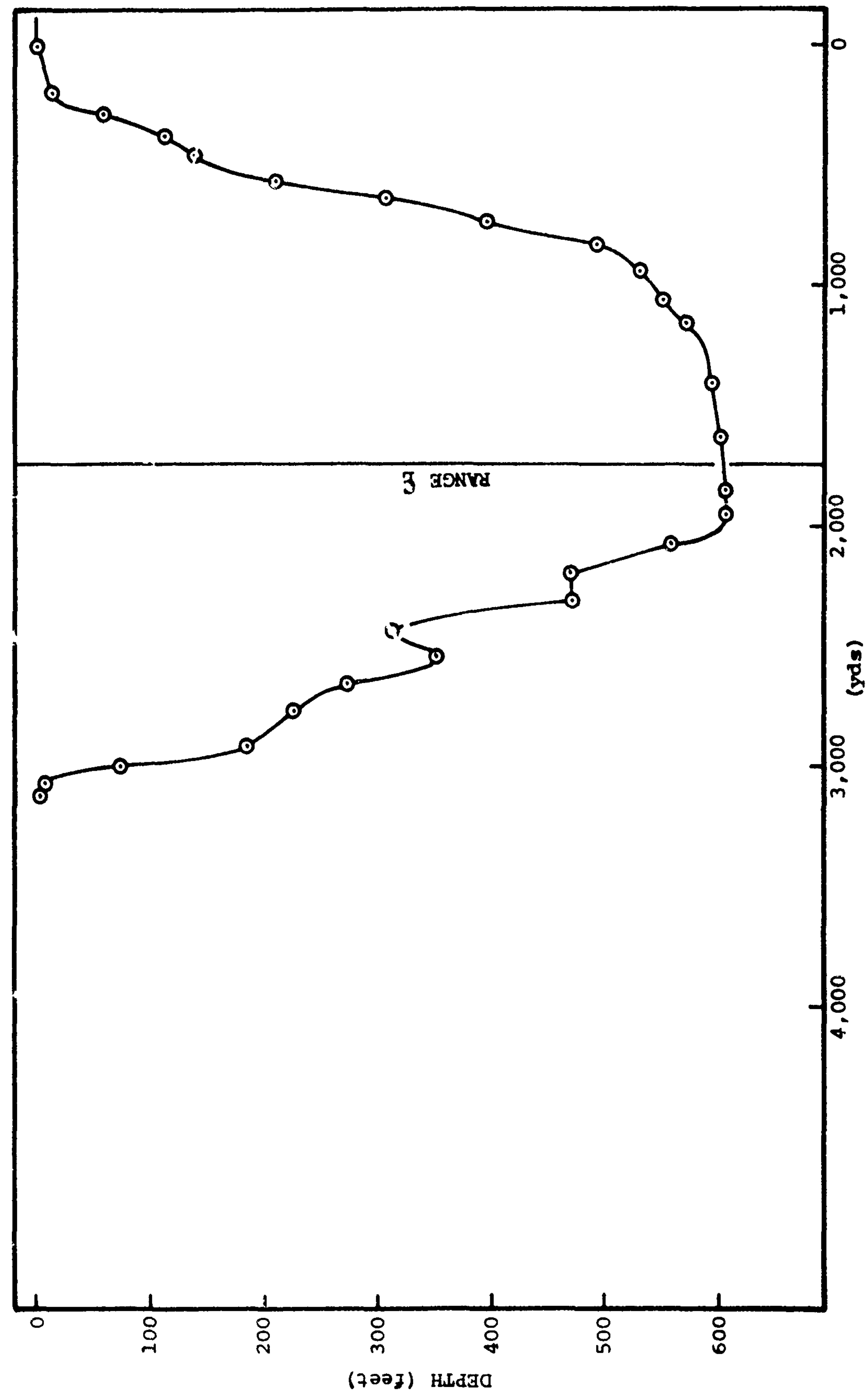

Figure 27. Dabob Basin Contour at Latitude 47°44'30" Vertical Exaggeration 15X

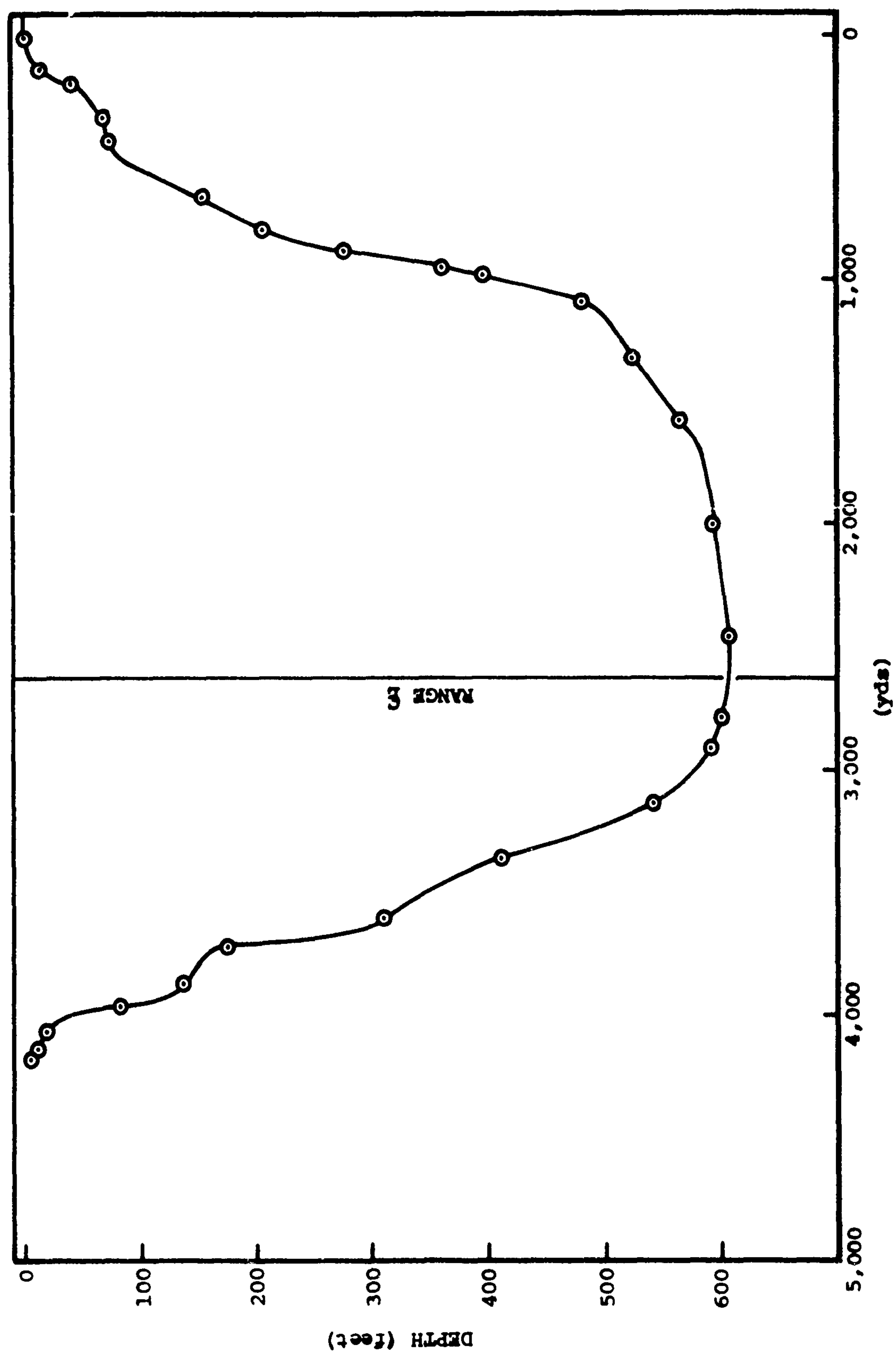

Figure 28. Dabob Basin Contour at Latitude 47°45'30" Vertical Exaggeration 15X

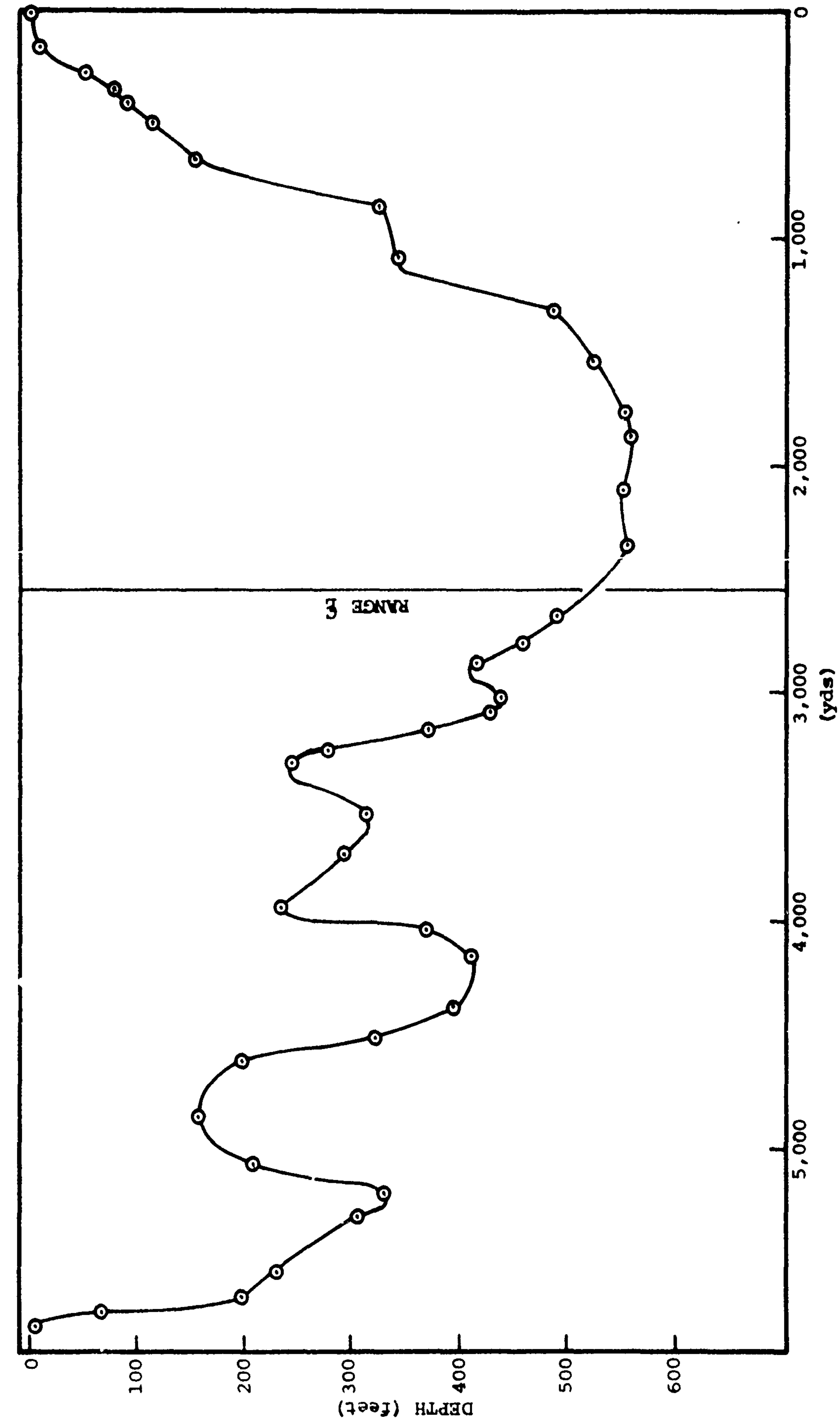

Figure 29. Dabob Basin Contour at Latitude 47°46'30" Vertical Exaggeration 15X

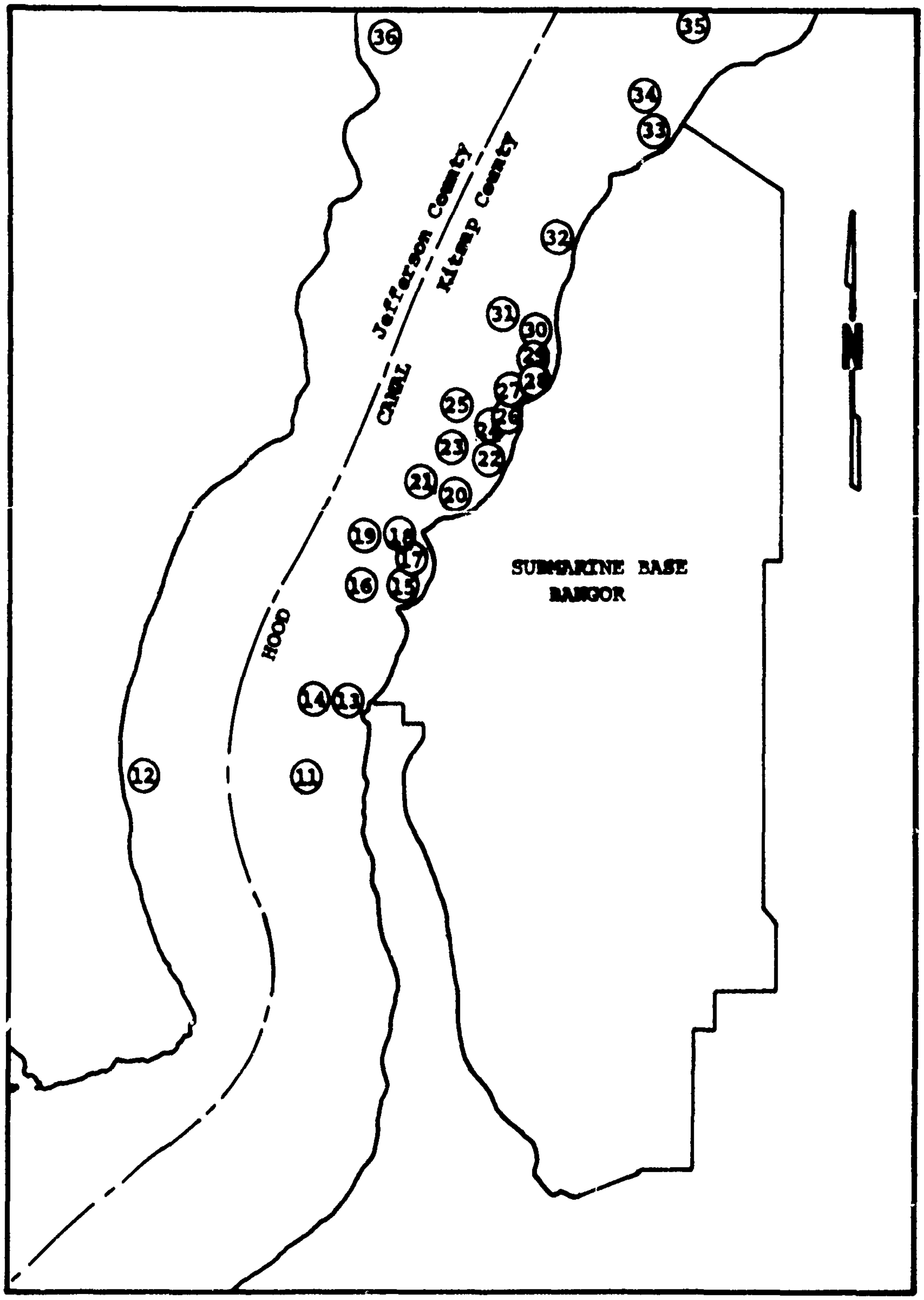

Figure 30. Sediment Sampling Stations

Table 5. Hood Canal Sediment Sample Characteristics

Station	Water Depth (ft)	Descriptors	% > 0.5mm (by weight)
11	80	Muddy fine sand, sand	13.4
12	80	Muddy fine sand	2.1
13	Intertidal	Muddy fine sand, sand	21.5
14	80	Muddy fine sand	4.7
15	Intertidal	Muddy fine sand, sand	36.8
16	80	Muddy fine sand	2.0
17	30	Muddy fine sand, sand	36.9
18	Intertidal	Muddy fine sand, sand	18.6
19	80	Muddy sand	64.6
20	Intertidal	Muddy sand	78.4
21	80	Fine sandy mud	1.9
22	Intertidal	Muddy fine sand	11.9
23	80	Muddy fine sand	3.2
24	Intertidal	Muddy fine sand	3.9
25	80	Muddy fine sand	5.0
26	30	Muddy, fine sandy mud	13.8
27	30	Sandy mud	12.4
28	Intertidal	Muddy fine sand	0.1
29	80	Fine sandy mud	0.2
30	Intertidal	Muddy fine sand, sand	31.9
31	80	Muddy sand, fine sand	23.8
32	Intertidal	Muddy fine sand, sand	36.8
33	Intertidal	Muddy fine sand	12.6
34	80	Muddy sand, fine sand	16.9
35	80	Muddy fine sand	0.2
36	80	Muddy fine sand	2.4

tion of the physical processes available for sediment transport. In Table 5, for example, the average percentages by weight of medium to coarse sand (no grade of gravel was reported in these samples) at intertidal, 30-foot and 80-foot depths are 25.2, 21.0, and 10.8 respectively.

In contrast to the thin-layer Shipek sampler sediment retrievals, the boring logs of Shannon and Wilson, Inc., and Haley and Aldrich, Inc.[19], reveal the presence of fine to coarse gravel in a significant number of instances out to depths of 90 feet. The bore-hole samplers acquire a sample in the topmost 1.5-foot stratum. In one instance a bore-hole sample (obviously obtained with little disturbance) showed sand, shell, and fines in the topmost 0.3 foot and sand, fines, and gravel in the 0.4-foot layer immediately below. These results of course, substantiate the findings generally observed with the thin-layer-retrieving Shipek sampler.

Most important, however, whatever the state of the surface sediment veneer (loose, hard, or dense/compacted), a harder underlaying layer most generally begins 3 to 50 feet below the mudline (contact with water) and consists of glacial till. Till is a very dense (low water content) mixture of sand, gravel, and silt. For all intents and purposes only bedrock could act as a better reflector and/or scatterer acoustically.

Atop the till and closer to the mudline, looser, less dense mixtures of sand, silt, some clay, and gravel are present. Sand is also an excellent reflector of acoustic waves.

Utilizing the available geotechnical data for Hood Canal, the coring device penetration data obtained by Linger, the surface sampling of Burns and Wang, and the available erosional and sediment transport processes, the following mudline conditions for the Dabob basin are postulated:

1. Intertidal zone (MHHW to MLLW (mean higher high water to mean lower low water)): a. volcanic rock; b. sand, gravel, and grading to boulders.

2. To 30 feet below MLLW: sand to coarse gravel, some silt.

3. To 100 feet below MLLW: sand to fine gravel, some silt.

[19] File No. 325101, *Results of Preliminary Borings and Laboratory Soil Tests - Trident Drydock, NTS Keyport, Bangor Annex, Washington*, Haley and Aldrich, Inc., Consulting Geotechnical Engineers and Geologists, Cambridge, MA, August 1974, unclassified

4. Basin slope region: fine to medium sand, some silt.

5. Basin bottom: silt/mud, some sand, fine gravel.

All the above zones can include traces of shell, and each is underlain by loose to dense glacial till-like material.

An overall summary of estimated bottom characteristics, then, is a mud and fine-sand texture on the bottom and lower slopes with coarser sand and fine gravel toward depths of 80 feet or less. Rock outscrops at Pulali point and tip of Bolton peninsula are minimally present. The thickness of loose noncompacted material (silty sand, sandy silt) varies to at least 4.5 feet, per the cores retrieved by Linger.

B. REFRACTION

An actual/typical sound speed profile was selected for each of the profile envelopes shown in Figure 14. The dates, times, and range positions for these profiles are given in Table 6.

Table 6. Typical Sound Speed Profile Identification

Profile	Month of Greatest Occurrence	Range Centerline Position (yds)	Date of Sample	Time
1	Feb	8,020	Jan 18 1971	0820
2	Apr	8,000	May 10 1971	0840
3	Jul	8,000	Jul 12 1971	0855
4	Sep	9,000	Sep 10 1971	0822
5	Sep	8,000	Sep 13 1972	0800

Ray diagrams for source depths of 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 350, 400, 450, and 500 feet were generated by computer for each sound speed profile in Table 6. For each diagram, rays were projected at each degree of angle from 12° down through 12° up, and their paths were plotted to a lateral range of 2 kiloyards. These diagrams are presented in Appendix C.

The diagrams can be used to predict:

1. Shadow zones for shallow depth sources.

2. Refraction-limited ranges for tracking.

3. Transmission loss variability at shallow angles from the horizontal.

4. Low acoustic intensity zones at moderate ranges created by refraction.

The diagrams will also engender appreciation of the acoustic medium itself.

C. VOLUME REVERBERATION

Anderson's ARTN's 76-7[20], 76-9[21], and 76-10[22] have identified up to 11 types of resident zooplankton in Dabob Bay. Most of these types exhibit the classical diurnal vertical migration patterns in response to light (closer to the surface at night and deeper during the daylight period). A luminous-equilibrium depth characteristic has also been observed wherein the zooplankton reside at shallower daytime depths on overcast cloudy days than on clear days.

More important, however, is the observed tendency of the scattering strength levels to change with the amount of plankton.

The column scattering strength, defined to be the scattering strength of 1 cubic yard of water at a given depth, has been measured at various times of the year. Anderson's ARTN's provide scattering strength profiles and should be consulted if the fine structure tendencies and identities of biotic types are desired. The following general statements serve to summarize the gross scattering strength characteristics of Dabob Bay:

1. Maximum daytime and nighttime scattering strengths (S_v) which have been observed at any depth are -64 dB and -61 dB respectively.

2. The vertical distribution of biota appears to be correlated with S_v.

3. A volume scattering strength which is dependent on pulse length over the range of 5 ms to 15 ms at either 30 kHz

[20] Applied Research Technical Note 76-7, *Reverberation Studies on Naval Torpedo Station's Acoustic Test Range in Dabob Bay During February 1974*, William B. Anderson, Naval Torpedo Station, Keyport, WA, June 1976, unclassified

[21] Applied Research Technical Note 76-9, *Reverberation Studies on Dabob Range for December 1974*, William B. Anderson, Naval Torpedo Station, Keyport, WA, June 1976, unclassified

[22] Applied Research Technical Note 76-10, *Reverberation Studies Conducted in Dabob Bay - Strait of Juan de Fuca - Pacific Ocean and Strait of Georgia (Nanoose) During May 1974*, William B. Anderson, Naval Torpedo Station, Keyport, WA, June 1976, unclassified

or 60 kHz is not apparent in the data obtained during 1974. Additional characteristics are summarized in Table 7.

D. SURFACE AND BOTTOM SCATTERING

The phenomenon of sound scattering by the air-sea interface (water surface) and the basin (bottom) boundaries is termed backscattering when boundary-incident acoustic waves return to the acoustic source. The time-variant backscattered level is termed a reverberation level at the transducer face or acoustic source. Surface and bottom backscattering share some common causes and exhibit some similar trends. For example, the boundary roughness caused by wind at the surface and by sediment size and texture at the bottom affect the boundary reverberation level. For grazing angles of 20° or less a variation in reverberation level can be expected for source tilt angle, source beam pattern, and medium refraction characteristics, which continually modify grazing angles out to the boundary ray limits and preclude boundary tangency past that limit. For examples, see ray diagrams for July at depths of 300 feet or greater in Appendix C.

There exist many references on measured values of boundary backscattering strengths from which known-geometry reverberation levels can be predictively calculated. Some of these values are representative of known boundary conditions and others are merely deduced or sparsely monitored. Barakos[23], JASA 1970[24], and Urick[25] summarize some of the values for backscattering strengths. With these data and the following Dabob Bay characteristics, an estimate of the boundary scattering/reverberation effects can be made.

1. The Dabob Bay bottom scattering surface is mainly composed of fine to medium sand, silt, and/or clay.

2. Local wind speed will affect surface roughness and aerated state. Figures 9 and 14 can be used to predict monthly occurrence of wind speeds (though not their duration).

3. Refraction/sound speed profiles will increase or decrease the boundary grazing angles, depending on source depth, time of year, and effective transducer beamwidth. The ray diagrams of Appendix C will facilitate the selection of relative testing geometries.

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[23] AD 451643, *Underwater Reverberation as a Factor in ASW Acoustics*, Peter A. Barakos, 11 September 1964, unclassified

[24] *Survey of Literature on Reflection and Scattering of Sound Waves at the Sea Surface*, JASA 1970, Vol 47:1209, unclassified

[25] *Principles of Underwater Sound for Engineers*, R. J. Urick, McGraw-Hill Book Co., Inc., New York, 1967, unclassified

Table 7. Scattering Strength (S_V) Characteristics and Zooplankton

Data Acquisition Period: Year	Month	Day	Daytime Period: Maximum Value of S_v (dB)	Frequency (kHz)	Depth (ft)	Nighttime Period: Maximum Value of S_v (dB)	Frequency (kHz)	Depth (ft)	Zooplankton: No. of Types Considered to Affect S_v	No. of Types Migrating Vertically
1974	Feb	7	-66.0	60	490	-67.0	60	190	4	4
	May	4	-64.0	30	550	-63.5	30	550	11	11
		5	-68.0	30	350	---	--	---		
		4	-66.0	60	550	-61.0	60	550		
		5	-66.0	60	550	---	--	---		
	Dec	10	-67.5	60	600	-68.0	60	550	10	7
		11	-67.0	60	590	---	--	---		
		10	-67.5	30	600	-67.5	30	580		
		11	-66.0	30	580	---	--	---		

Variation of boundary backscattering characteristics with frequency is published in various sources but direct applicability to Dabob Bay bottom reverberation levels awaits experimental determination.

For initial reverberation level estimating purposes the following parameter ranges can be used:

1. Bottom scattering strength $S_b \leq -20$ dB

2. Surface scattering strength $S_s \leq -25$ dB (can vary between -35 dB to -25 dB depending on wind speed and frequency)

3. Volume scattering strength $S_v \leq -60$ dB

For most testing conditions, the bottom reverberation level in the shallow-water Dabob environment will be the limiting reverberation factor.

E. TRANSMISSION LOSS

The specification/determination of acoustic transmission loss in shallow water is quite difficult. Here shallow water is defined as water in which sound propagation to a distant point involves reflection(s) from one or both boundaries.

For example, the placement of source and receiver in the vertical plane, the conditions of the water surface with regard to reflection and scattering, and a non-homogeneous texture of the bottom all combine to distort the received pulse.

In a CW reverberent field at moderate range, the transmission loss characteristics of the shallow water environment are predictable within narrower confidence intervals. The model of shallow water transmission loss characteristics in BBN Report 1563[26] has been verified as applicable in Dabob Bay; see BBN Report 1688[27].

The result of this model is:

$$TL = 15 \log r + \alpha r + K \text{ dB, i.e.,}$$

a mathematically resultant compromise between cylindrical and spherical spreading loss plus linear absorption loss plus K dB.

[26] BBN Report 1563, *Sound Transmission in Shallow Water, Part 1: Analysis*, P.W. Smith, Jr., Bolt, Beranek, and Newman, 24 October 1967, unclassified

[27] BBN Report 1688, *Characteristics of Sound Propagation in the Dabob Bay and Nanoose Ranges as They Relate to Torpedo Radiated Noise Data*, Bolt, Beranek, and Newman, Inc., September 1968, confidential

In this equation, r is the lateral range in kiloyards and α is the volumetric attenuation in dB per kiloyard. The determination of K based upon BBN Report 1563 is included in Appendix D.

F. AMBIENT NOISE

Ambient noise level is conditional upon many parameters. These are not always specified because the measurement conditions are not all determined or known with certainty. In contrast to this norm the levels shown in Figure 31 are representative of the following conditions:

Graph 1: All range craft machinery secured (Signal 0) no other craft in sight in the ranging area. This graph represents the natural sea state 0 environment noise.

Graph 2: Same machinery conditions as above but it was raining and the wind speed was 15 mph.

Graph 3: Signal 1 lineup of range craft (YF 451) machinery (one 10-kW motor generator and one each 60-kW dc and 10-kW ac diesel-driven generator operating and two 500-hp main propulsion engines idling but declutched). Range craft 300 yards from measurement hydrophone array at bow-beam aspect. Sea state 0. No additional noise sources observed.

With ranging precautions and weather permitting, the general ambient noise level can be expected to lie between curves 1 and 2. Precautions entail the quieting of range craft and spotting of public craft. The waiting out of bad weather, if schedules will permit, is also advisable if natural ambient noise contamination will be troublesome.

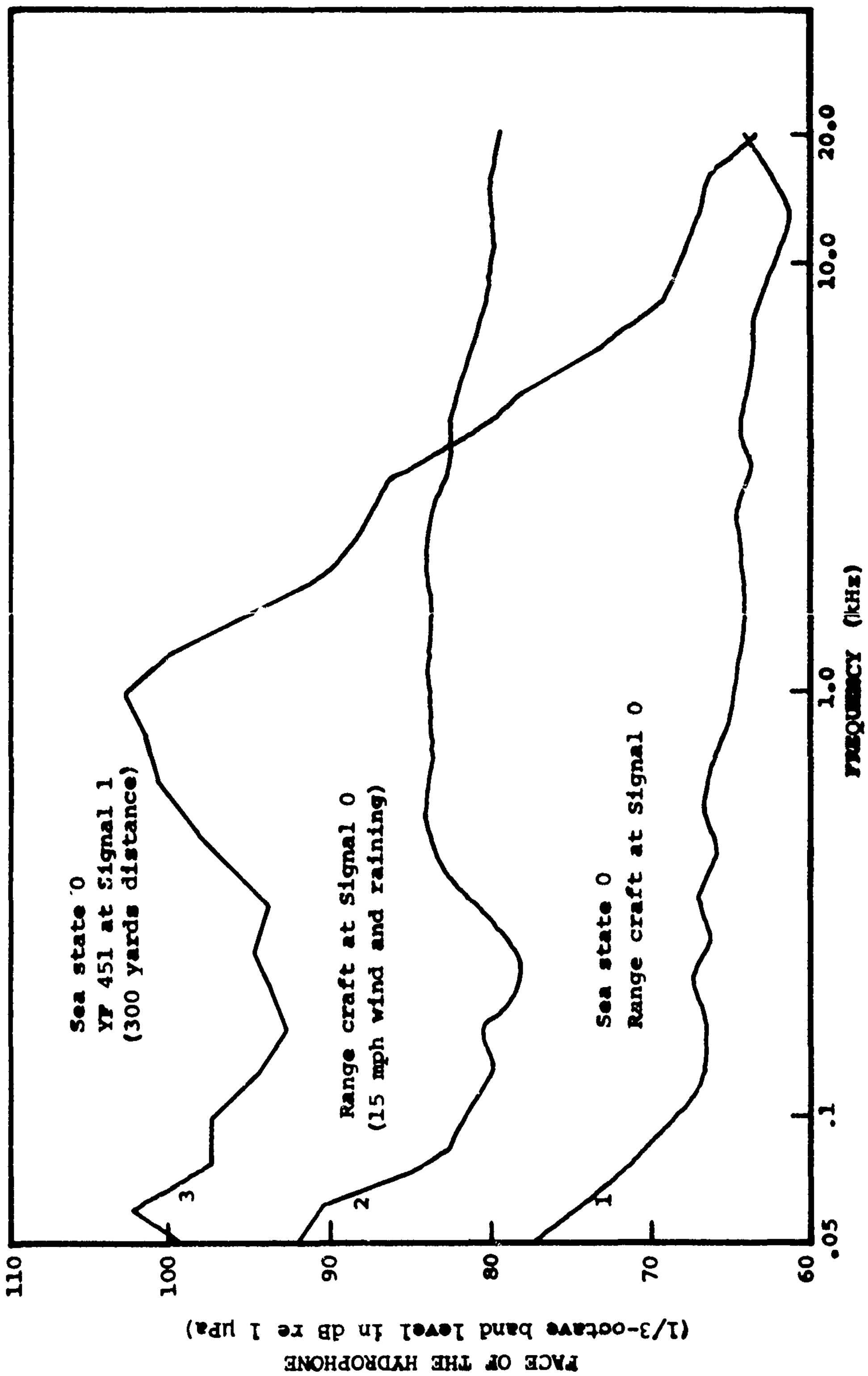

Figure 31. Typical Dabob Bay Ambient Noise Levels

5. GENERAL PARAMETERS

A. DENSITY

The recovery of low reserve buoyancy devices in Dabob Bay has occasionally been troublesome due to the equilibrium depths involved. Table 8 shows the variation in σ_t with depth and time of year (σ_t = (density-1)x1000).

Thus the density at 30-foot depth on 12 July 1971 was 1.02070 gm/cm^3. (See profile 3 of Table 6.) Density was determined from the tables of *Special Publication SP-65*[28].

Table 8 illustrates the seasonal variation in surface layer conditions as evidenced by the density gradients and the absolute density variation. In the May to early-July period, per the table, the maximum runoff has occurred and the surface layer is approaching its maximum temperature, thus producing the minimum surface layer density of the period. During the fall and winter period the runoff is lower and so are the temperatures. Surface layer salinity and density therefore increases.

The yearly density variation of Dabob Bay waters is exemplified by Figure 32. In this figure are plotted the maximum and minimum σ_t values versus depth from Table 8. From consideration of the possible runoff and temperature conditions during the June-July period, a density minimum of 1.018 gm/cm^3 at 10-foot depth is quite likely, with a value as low as 1.017 gm/cm^3 certainly possible.

Range users, therefore, must provide for adequate reserve buoyancy in near-surface density ranging between 1.017 - 1.023 gm/cm^3 if normal recovery is desired. Also to be noted are the following:

1. Cells of water of differing density are known to reside at most depths over most of the range areal extent (see Kollmeyer's thesis and Ebbesmeyer's thesis).

2. The surface layer density is dependent on runoff, which is difficult to predict.

[28] Special Publication SP-65, *Handbook of Oceanographic Tables*, U. S. Naval Oceanographic Office, Washington, DC, 1966, unclassified

Table 8. Typical Density Values for Dabob Bay
σ_t = (density-1) 1,000

Depth (ft)	PROFILE 1 Jan 18 1971 (σ_t)	PROFILE 2 May 10 1971 (σ_t)	PROFILE 3 Jul 12 1971 (σ_t)	PROFILE 4 Sep 10 1971 (σ_t)	PROFILE 5 Sep 13 1972 (σ_t)
Surface	22.578	18.493	19.666	20.368	20.648
10	22.578	20.250	20.090	20.460	20.648
30	22.720	22.584	20.702	22.504	22.285
50	23.113	23.123	22.395	22.801	22.739
100	23.887	23.518	22.710	23.456	23.198
200	24.077	23.771	22.926	23.463	23.411
300	24.184	23.851	22.919	23.525	23.462
400	24.292	24.076	23.202	23.570	23.472
500	24.320	24.275	23.478	23.851	23.733

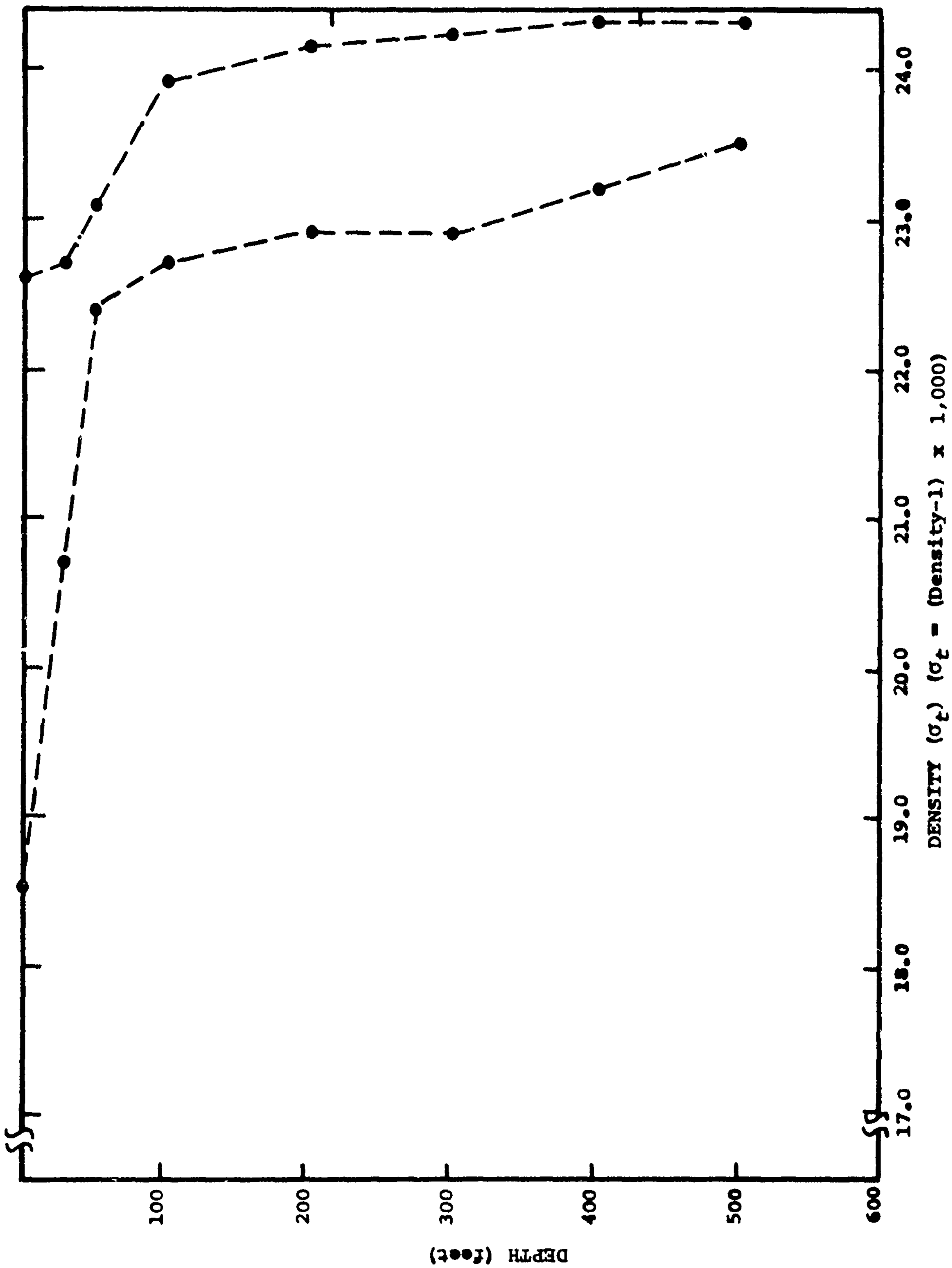

Figure 32. Dabob Bay Density Profile Envelope

3. If reserve buoyancy at a water density of 1.017 gm/cm^3 to 1.018 gm/cm^3 is not available an updated check of surface layer conditions should be pursued.

4. For depths greater than 100 feet the density gradient is quite low.

B. TIDES AND CURRENTS

Dabob Bay has a mixed tidal cycle; it consists of both diurnal and semidiurnal components, dependent upon the time of month or year. The diurnal cycle has one high and one low tide per day and the semidiurnal cycle two of each. Figure 33 presents a typical mixture of the tides for the Dabob Bay range. The tidal range varies throughout the year. The extremes range from approximately -4.5 to +15.3 feet.

The tidal corrections from data based upon Seattle tides are -03 minutes and approximately +0.3 foot. Thus a 10-foot tide at 0800 in Seattle corresponds to a 10.3-foot tide at 0757 at Dabob Bay.

The currents have been measured by Savonius rotor and drift bottle-type instruments. Short-term data measured using the latter type instrument is reported in APL/UW 60-35[29], and APL/UW 6522[30]. These documents essentially indicate that the current speed is less than 0.15 knot at depths greater than 100 feet.

A long-term (45-day) current measurement awaits execution. It will better definitize the tidal components and directions and hopefully expose any wind-induced (surface-level-slope-change-induced) mid-depth flows.

[29] APL/UW 60-35, *Measurement of Deep Currents with a Submergible Drift Bottle*, G.R. Garrison et al, Applied Physics Laboratory, University of Washington, 3 May 1961, unclassified

[30] APL/UW 6522, *Measurement of Subsurface and Bottom Currents 1961-1964*, G.R. Garrison, Applied Physics Laboratory, University of Washington, 28 July 1965, unclassified

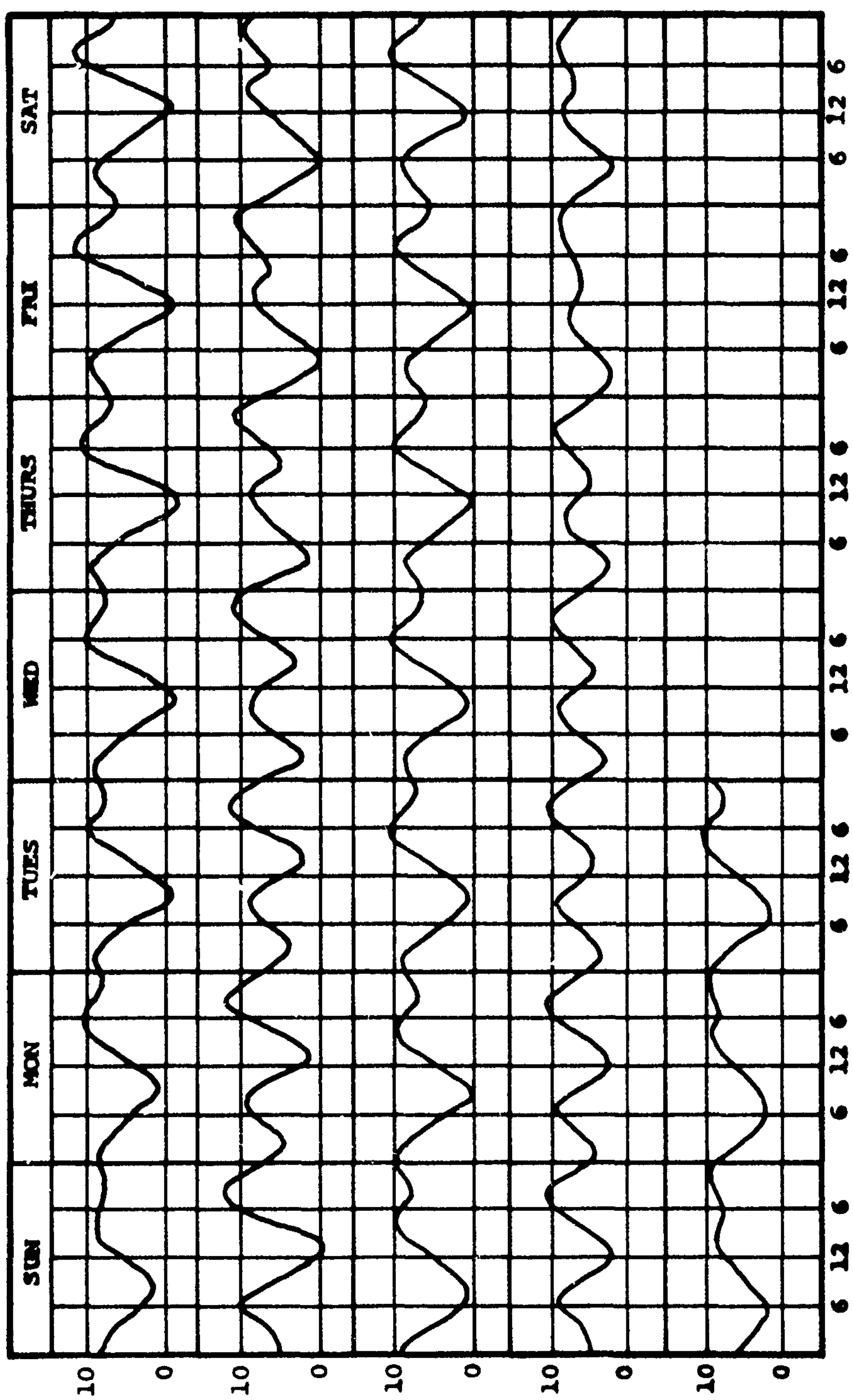

Figure 33. Typical Tide Curves for Seattle

6. SCHEDULING PRECAUTIONS

Attention to the information and data presented in this report will assist range users and prospective users in planning and carrying out operations in the Dabob Bay range. Particular note should be taken of the following:

1. Tests sensitive to sound refraction anomalies should be conducted in November, when the anomalies are lowest, or in March or April, when they are next lowest. See page 35.

2. If a test requires that ambient noise be at minimum, scheduling should allow for delays due to weather and sea state.

3. In June and July, if surface recovery of the device ranged is planned, it must be recognized that because of temperature and fresh-water intrusion, near-surface water density may be as low as 1.017 gm/cm^3.

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27. BBN Report 1688, *Characteristics of Sound Propagation in the Dabob Bay and Nanoose Ranges as they Relate to Torpedo Radiated Noise Data*, Bolt, Beranek, and Newman, Inc., September 1968, confidential

28. Special Publication SP-65, *Handbook of Oceanographic Tables*, U. S. Naval Oceanographic Office, Washington, DC, 1966, unclassified

29. APL/UW 60-35, *Measurement of Deep Currents with a Submergible Drift Bottle*, G. Garrison, et al, Applied Physics Laboratory, University of Washington, 3 May 1961, unclassified

30. APL/UW 6522, *Measurement of Subsurface and Bottom Currents 1961-1964*, G. R. Garrison, Applied Physics Laboratory, University of Washington, 28 July 1965, unclassified

Appendix A

SOUND SPEED/TEMPERATURE AND SALINITY PROFILES DATA BASE

Range ℄ Positions (Page 1 of 8)

(k = kiloyards)

Date	2k	4k	6k	8k	10k	11 to 11.5k	11.5 to 12k
Jan 5 1971	x	x	x	x	x		x
12	x	x	x	x	x		x
18		x	x	x	x		x
22		x	x	x	x	x	
Feb 1		x	x	x	x		
5	x	x	x	x	x		x
11		4.75	x	x			
18		3.6	5.35	x	9.85		11.85
22			x	x	x		x
23		3.6		x	x		x
Mar 1	x	x	x	x	x		x
5	x	x	x	x	x		x
9		3.55		8.2			
13	x	x	x	x	x		x
19	x	x	x	x	x		x
25	x	x	x	x	x		x
30	x	x	x	x	x		x
Apr 6	x	x	x	x	x		x
9		x	x	x	x		x
13			x	x	x		x
21	x	x	x	x	x		x
23	x	x	x	x	x		x
29		x	x	x	x		x
30		x	x	x			
May 4			x	x	x		x
10			x	x	x		x
11	x	4.55	x	x	x		x
14		x		x	x		x
18	x	x	x	x	x		x
21	x	x	x	x	x		x
27	x	x	x	x	x		x
Jun 3	x	x	x	x	9.4	x	
8			x	x	x		
11		x	x	x			x
16	x	x	x	x	x		x
21				x	x		x
25	x	x	x	x	x		x
28	x	x	x	x	x		x

Range ℄ Positions (Page 2 of 8)

(k = kiloyards)

Date	2k	4k	6k	8k	10k	11 to 11.5k	11.5 to 12k
Jul 6 1971		x	x	x	x		x
12	x	x	x	x	x		x
19	x	x	x	x	x		x
21		x	x	x			
27		x	x	x	x		x
29				x	x		x
Aug 2	x	x	x	x	x		x
6			x	x	x		x
17	x	x	x	x	x		x
23		x	5.8				
24	x	x	x	x	x		x
25		x	x	x	x		
Sep 3	x	x					
10		x	x	x	9.0		x
15	x	x		x	x		x
16	x	x	x	x	x		x
22	x	x					
23	x	x					
30				x			x
Oct 1	x		x		x		
4	x	x	x	x	x		x
7	x	x	x	x	x		x
13	x	x		x			
15	x	x		x			x
28	x	x	x	x			
Nov 22	x	x					
Dec 28	x	x	x	x	x		x
Jan 12 1972	x		x	x	x		
21			x	x			
28			x	8.2			
Feb 7		x	x	x	x		
11		x		7.7			
15		x	x	x			
17	x	x	x	x			x
23	x	x	x		9.8		
24				8.15			12.9
25	x		x		x		
Mar 1		x	5.7	x	x		
7			x		x		
10			5.5	8.3	x		
15		3.55	x	x			
21			x	x	x		
23				x			x
29		4.75		x			
31				8.4	10.4		x

Range ℄ Positions (Page 3 of 8)

(k = kiloyards)

Date	2k	4k	6k	8k	10k	11 to 11.5k	11.5 to 12k
Apr 5 1972		x	x				
10	x	x	x		x		
12	2.45	3.6	5.5	8.4	10.4		
17	x	x	x				
19		3.75	x	7.8	x		
21	2.7	3.65	4.75				
26			x	x	x		
28	x	x	x	x			
May 1	x	x	x	x	x		x
3	x	x	x	x			
8	x	x	x	x			
11		x	x	x	x		
16			x	x	x		
26	x	x	x	x	x		
30	x	x	x	x	x		
Jun 2			x	x	x		
7		5.0	x	x	x		
12	x	x	x				x
16			x	x			
22		3.6	5.7	8.35			
29		3.7	x	x	x		x
30		x		x	x		
Jul 6		x	x		x		
12	x		x				
20				x			x
21		x		x			
26		x		8.6			
27			5.7	8.2	x		
Aug 2	x	x	x	x	9.7		x
4	x	x	x	x	x		x
10	x			x	x		x
11			x		x		x
14	2.2	x	x	x	x		
16		x	x	x	x		x
24	x			x	x		
31			x	x	x		
Sep 6		x	x	x			
13		x		x			
20	x	x	x				
28				x	x		
29		x	x	x	x		x
Oct 4		3.7		x			
5		4.7	x	x	x		
13		4.5		3.4			
18		x	x	x	x		x
19	x	x	x	x	x		

Range ℄ Positions (Page 4 of 8)

(k = kiloyards)

Date	2k	4k	6k	3k	10k	11 to 11.5k	11.5 to 12k
Oct 24 1972		x	x	x			
25		3.65		x	x		x
26		x		x			
Nov 8			5.6	x	x		
15			x	x	x		
20		x	x	x			x
22			x	7.8	x		x
29	x	3.7	5.8				
30				x			x
Dec 4			x	8.4	9.7		x
5	x	x	x	8.4			
11		3.75		8.4			x
13		3.75		8.4			x
15		x	x	x	x		x
20		x	x	7.3			x
21	x	x	x	x	x		x
27		x	x				x
29					x		x
Jan 15 1973	2.7			8.4	9.7		
17			x		x		
18	x	x	x		x		
22	2.65	3.75	5.8				
24		3.75	x		x		
26			x		x		
Feb 1		3.7		8.4			x
8			x	x	x		
14				x	x		x
20			x	x	x		x
22			x	x	x		x
27			7.73	x			
Mar 1				8.4	10.2		
7			x	x	x		x
15			x	x	x		
21				8.4			x
22		x	x	x	x		
26			x	x			
28			x	x	x		
Apr 2				x	x		x
4		x	x	x			
6			x	x			
16		x		x			x
18			x	x	x		
25			x	x	x		
27			x	x			
30			x	x			

Range ℄ Positions (Page 5 of 8)

(k = kiloyards)

Date	2k	4k	6k	8k	10k	11 to 11.5k	11.5 to 12k
May 2 1973		x	x	x	x		
8		x		8.4			x
11		x		8.4			
22				x	x		
24			x	x	x		x
29		x		x	x		
31		4.75	x	x	x		
Jun 6		4.75	x		x		
8		x	x	x	x		x
13		4.25		7.5	x		
19		x		x	x		
22		x		x			x
26		x	x	x	x		x
28				x	x		x
Jul 5				x	x		x
12			x	x	x		
18		x	x	8.[illegible]	x		
20		x	5.8	x	x		x
26		4.75	x	x	x		
30		x		x			x
31	x		x		x		
Aug 1			x	x	x		
8		x	x	x	x		
10		x			x		
15		[illegible].3		x			
24			x	x	x		
30	x	x	x				
31		x	x	x	x		
Sep 4			x		x		
6	x	x	x				
12			x	x	x		x
19			x	7.8			
20			5.7	x	x		
28			x	x	x		
Oct 2			x		x		
15		x	x	x	x		x
16		3.1	x	x	x		
18	x	x	x	x			x
24		3.1		8.4	10.1		
31	x	x	x				
Nov 13		4.75		8.4	x		
14		4.25		8.4		x	
16		x			x		
21		x			x		

Range ℄ Positions (Page 6 of 8)

(k = kiloyards)

Date	2k	4k	6k	8k	10k	11 to 11.5k	11.5 to 12k
Dec 6 1973		4.25		8.4	x	x	
13		4.75		8.4	x		
14					x	x	
17		x		x	9.55		
Jan 3 1974		4.75		8.4	9.55		
9		x	x	x	x		x
17		x		x	x		
21				8.4	x		
31		4.75			9.55		
Feb 5			x		9.5		
12				8.4	x		
19				x	9.5	x	
20		x		8.4	9.5		
21		x	x		x		
Mar 1		x	x				
7				x	x		
20				x	x		x
25		4.25	x	x	x		x
26		4.25	x	8.4			
29			x	x			
Apr 2		x		x	x		
5		x		x	x		
10			x	x	x		
17		x	x	x	x		x
23		x		x	x		
26		x	x	x	x		x
30			x		x		
May 7		4.25			9.55		
14			5.5		9.8		
15		4.25	x	x	x		x
16		x	x	x			
22		3.8	x	x	x		x
24		4.25		x			
Jun 5		x			x		
11		x	x	8.4			
17		x	x				x
21		x		x			
25			6.2		9.55		
26			x	x	x		
28		x		x			
Jul 2			x	x	x		
8		x	x	x	x		x
18		4.25		8.4	9.55		
31		x		8.4			

Range ℄ Positions (Page 7 of 8)

(k = kiloyards)

Date	2k	4k	6k	8k	10k	11 to 11.5k	11.5 to 12k
Aug 13 1974		x	x	8.15	x		x
19		x		x	x		
22		x		x	x		
26		x		x	9.55		
28			x	x			x
29		x		x			
Sep 3		x		8.95		x	
5		x		x		x	
10		4.6		8.4			x
13		4.6	x		x		
18				8.4	x		x
Oct 2				x			x
7	x	4.6	x	8.4	x		
15				8.4	x		
17				x	x		
22		x		8.95	x		
23				x	x		
31		x	x	x	x		
Nov 7	x	x	x	x	9.7		
12		x	x	x	x		x
13	x	x	x	x	x		
Dec 3				x			x
17				x			x
23				8.4		x	
Jan 6 1975				x			x
16		3.1	5.8		9.8		x
Feb 4		x	x	x	x		x
7		x		x			
13				x	x		
14		x	x	x			
27		4.6		8.85		x	
Mar 4				8.4	9.8		
12			5.8	8.4			
26			5.8	7.9	9.8		
27				x	x		x
Apr 2		x	x				
8		3.1	5.9	x	x		x
15			5.6	8.4			x
16		x	x	x	x		x
25		x	x	7.8	x		x
30		x		x			

Range ℄ Positions (Page 8 of 8)

(k = kiloyards)

Date	2k	4k	6k	8k	10k	11 to 11.5k	11.5 to 12k
May 7 1975		x		x			
14		3.8		7.8			x
20		x		x		x	
28			x	x	x	x	
Jun 5		x		7.7			
13		3.9	6.6	8.5			
23		x	x	x			
26		x	6.6	8.85			
Jul 10				8.4		x	
21		x	x	x	x		x
29		3.1	x	x	9.8		
Aug 12		3.1	x	x	x		x
21			6.4	8.2		x	
Sep 5			x	8.4			
19		x	x				
25				8.6		x	
Oct 6				8.6			x

Appendix B

DELINEATION OF PROFILE ENVELOPE ROUGHNESS

Table B-1. Incidence of Sound Speed Roughness to 5 ft/sec
(Rough = > 5 ft/sec spread; Smooth = ≤ 5 ft/sec spread)

Year		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1971	Rough	12,18,22	1*,5,11*, 18	5,13,19, 25,30	23,29,21	14,18,27	3,16,21, 25,28,8*	6,12,19, 21*,27	2,6,17, 23*,24, 25*	3*,10,15 16,22*, 23*,30	1*,4,15, 28*		28
	Smooth	5	22,23	1,9*	6,9,13,30*	4,10,11,21	11	29			7,13*	22*	
1972	Rough	12*,21*	7*,11*,17, 23*,24, 25*,15*	1*	10*,12*	16*,26*,30*	7*,12,16*, 22*,29,30*	6*,12*,26*, 27*	2,4,10, 11,14*,16 24*,31*	6*,13*, 20*,28*, 29	4*,5*,18, 19*,24*, 25	30	5*,11,13, 20,15
	Smooth	28*		7*,10*, 15*,21*, 23 ,29*,31	5*,17*, 19*,21*, 26*,28*	1,3*,8*, 11*	2*	20,21*			13*,26*	8*,15*, 20,22,29*	4,21,27,29
1973	Rough	15*,17*, 18*,24*, 26*	1,8*	7	16,25*	8,24,29*, 31*	6*,8,13*, 19*,22,26, 28	5,12*,18*, 20,26*,30	1*,8*,30*, 15*,24*, 31*	4*,6*,12, 20*		13*,14	6,13*,14
	Smooth	22*	14,20,22, 27*	1*,15*,21, 22*,26*, 28*	2,4*,6*, 18*,27*, 30*	2*,11*,22*		31*	10*	19*,28*	2*,15,16*, 18,24*,31*	16*,21*	17*
1974	Rough	17*	5*	26*		7*	28*,11*, 17,5*	2*,8,18*, 31*	13,19*,22*, 26*,28,29*	3,5,10,13*, 18	2,22*,23*		17
	Smooth	3*,9,21*, 31*	12*,19, 20*,21*	1*,7*,20, 25,29*	2*,5*,10* 17,23*,26, 30*	14*,15,16* 22,24*	21*,25*,26*				7*,15*, 17*,31*	7*,12,13*	3,23
1975	Rough	16	13*,14*, 27	26*,27	2*,25,8, 15,16	7*,14	5*	10,21,29*	12,21	5*	6		
	Smooth	6	4,7*	4*,12*	30*	20,28	13*,23*, 26*			19*,25			

*Means no profile data was obtained at range centerline positions in excess of 10.5 kiloyards

Table B-2. Incidence of Sound Speed Roughness to 7.5 ft/sec
(Rough = > 7.5 ft/sec spread; Smooth = ≤ 7.5 ft/sec spread)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1971	Rough	18,22	1*	13,19		27	25,28	12,27	6,24,25*	3*,10,15, 30,16	1*,4,28*		28
	Smooth	5,12	5,11*,18, 22,23	1,5,9*, 25,30	6,9,13, 21,23,29, 30*	4,10,11, 14,18,21	3,8*,11, 16,21	6,21*,29, 19	2,23*,17	22*,23*	7,13*,15	22*	
1972	Rough	12*,21*	7*,11*,17, 23*,25*,15*	1*	12*	26*,30*	7*,12,16*, 22*,29	6*,12*, 26*,27*	2,4,10,11, 14*,16,24*, 31*	6*,13*, 20*,28*, 29	5*,18,19*		5*,11,13, 15,20
	Smooth	28*	24	7*,10*, 15*,21*, 23,29*,31	5*,10*, 17*,19*, 21*,26*,28*	1,3*,8*, 11*,16*	2*,30*	20,21*			4*,13*, 24*,25,26*	8*,15*,20, 22,29*,30	4,21,27, 29
1973	Rough	15*,17*, 18*,24*	1	7		24	6*,8,13*, 22,26,28	18*,20,26*	15*,24*, 31*	4*,6*,12, 20*			6
	Smooth	22*,26*	8*,14,20, 22,27*	1*,15*, 21,22*, 26*,28*	2,4*,6*, 16,18*, 25*,27*,30*	2*,8,11*, 22*,29*,31*	19*	5,12*,31*, 30	1*,8*,10*, 30*	19*,28*	2*,15,16*, 18,24*,31*	13*,14, 16*,21*	13*,14, 17*
1974	Rough	17*					11*,28*, 17	18*,31*,8	13,19*, 22*,26*, 28,29*	3,5,10,13*	2,22*		
	Smooth	3*,9,21*, 31*	5*,12*,13, 20*,21*	1*,7*,20, 25,26*,29*	2*,5*,10*, 17,23*,26, 30*	7*,14*,15, 16*,22,24*	5*,21*, 26*,25*	2*		18	7*,15*, 17*,23*, 31*	7*,12,13*	3,17,23
1975	Rough	16	13*,14*,27	26*,27	2*	14			12,21	5*	6		
	Smooth	6	4,7*	4*,12*	8,15,16, 25,30*	7*,20,28	5*,13*, 23*,26*	10,21,29*		19*,25			

*Means no profile data was obtained at range centerline positions in excess of 10.5 kiloyards

Table B-3. Incidence of Sound Speed Roughness to 10 ft/sec
(Rough = > 10 ft/sec spread; Smooth = ≤ 10 ft/sec spread)

Year		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1971	Rough	18,22	1*	13,19			25,28		6,24,25*,	3*,15,16 30	1*		28
	Smooth	5,12	5,11*,18, 22,23	1,5,9*, 25,30	6,9,13,21, 23,29,30*	4,10,11, 14,18,21, 27	3,8*,11, 16,21	6,12,19, 21*,27,29	2,17,23*	10,22*,23*	4,7,13*, 15,28*	22*	
1972	Rough	12*,21*	11*,17, 23*,25*.15*				12,16*		2,4,10, 11,14*,16, 24*,31*	13*,6*,20*	5*,18,19*		20,13
	Smooth	28*	7*,24	1*,7*,10*, 15*,21*, 23,29*,31	5*,10*, 12*,17*, 19*,21*, 26*,28*	1,3*,8*, 11*,16*, 26*,30'	2*,22*,7*, 29,30*	6*,12*, 20,21*, 26*,27*		28*,29	4*,13*, 24*,25,26*	8*,15*, 20,22, 29*,30	4,5*,11, 15,21, 27,29
1973	Rough						8,22,26, 28		15*,31*	4*,6*,12			6
	Smooth	15*,17*, 18*,22*, 24*,26*	1,8*,14, 20,22,27*	1*,7,15*, 21,22*, 26*,28*	2,4*,6*, 16,18*,25*, 27*,30*	2*,8,11*, 22*,24, 29*,31*	6*,13*,19*	5,12*, 18*,20, 26*,30,31*	1*,8*,10*, 24*,30*	19*,20*, 26*	2*,15, 16*,18, 24*,31*	13*,14, 16*,21*	13*,14, 17*
1974	Rough	17*						18*	13,19*, 26*,28	3,5,10, 13*			
	Smooth	3*,9,21*, 31*	5*,12*, 19,20*,21*	1*,7*,20, 25,26*, 29*	2*,5*,10*, 17,23*,26, 30*	7*,14*, 15,16*, 22,24*	5*,11*, 17,21*, 25*,26*,28*	2*,8,31*	22*,23*	18	2,7*,15*, 17*,22*, 23*,31*	7*,12,13*	3,17,23
1975	Rough			26*,27		14			21	5*			
	Smooth	6,16	4,7*,13*, 14*,27	4*,12*	2*,8,15, 16,25,30*	7*,20,29	5*,13*, 23*,26*	10,21,29*	12	19*,25	6		

*Means no profile data was obtained at range centerline positions in excess of 10.5 kiloyards

Appendix C

SOUND RAY DIAGRAMS

Figures C-1 through C-90

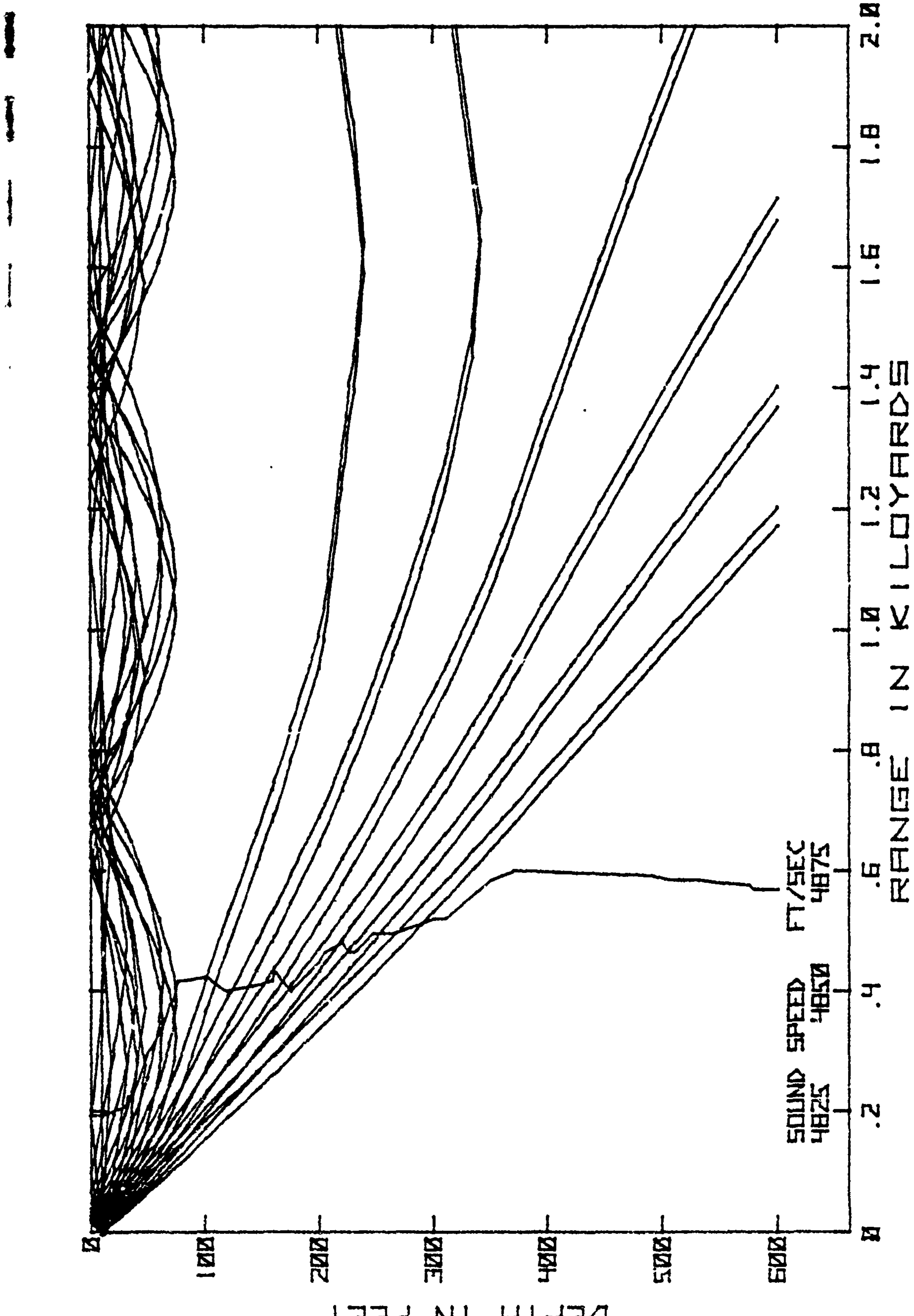

FIG. C-1. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 10 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

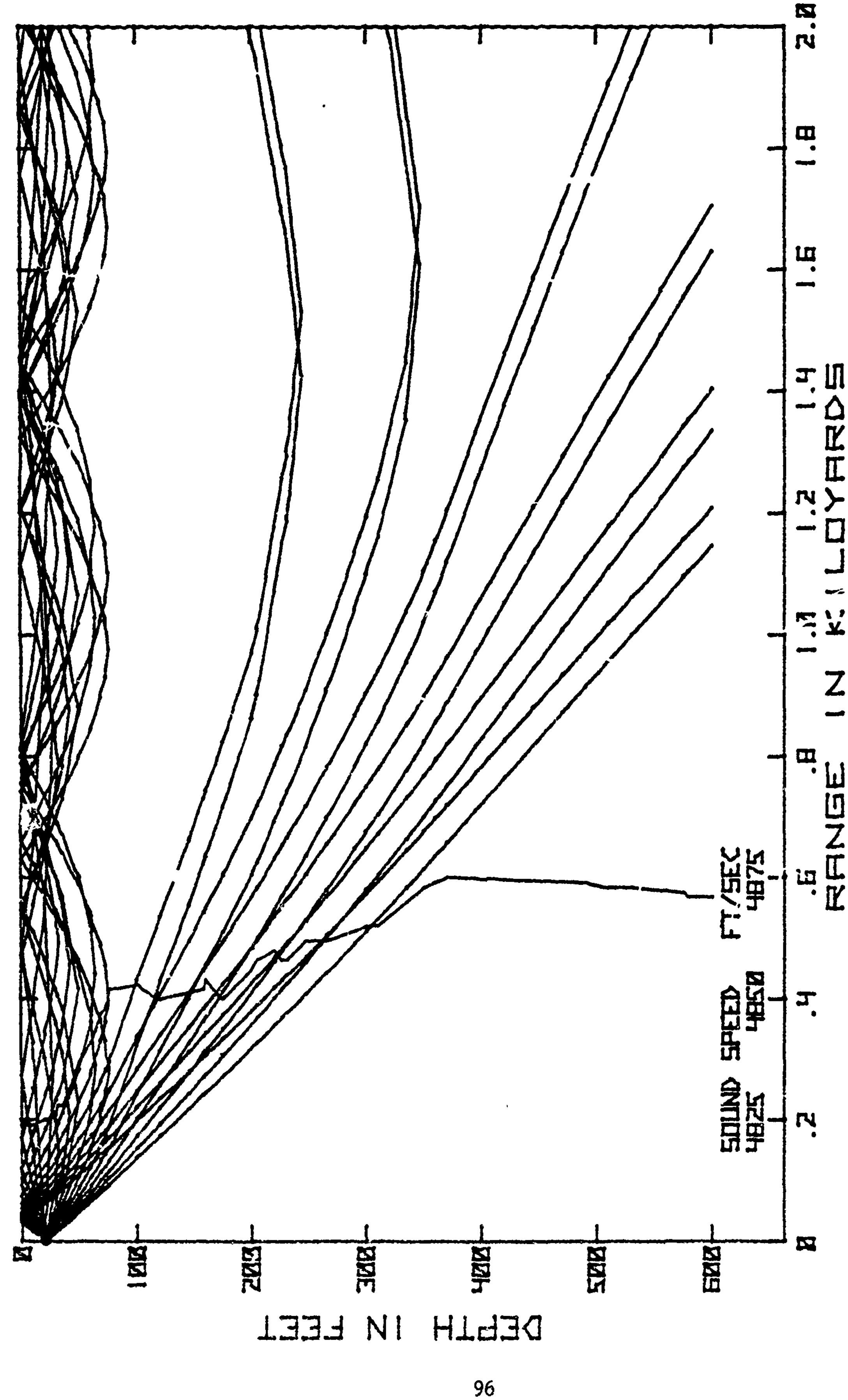

FIG. C-2. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 20 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

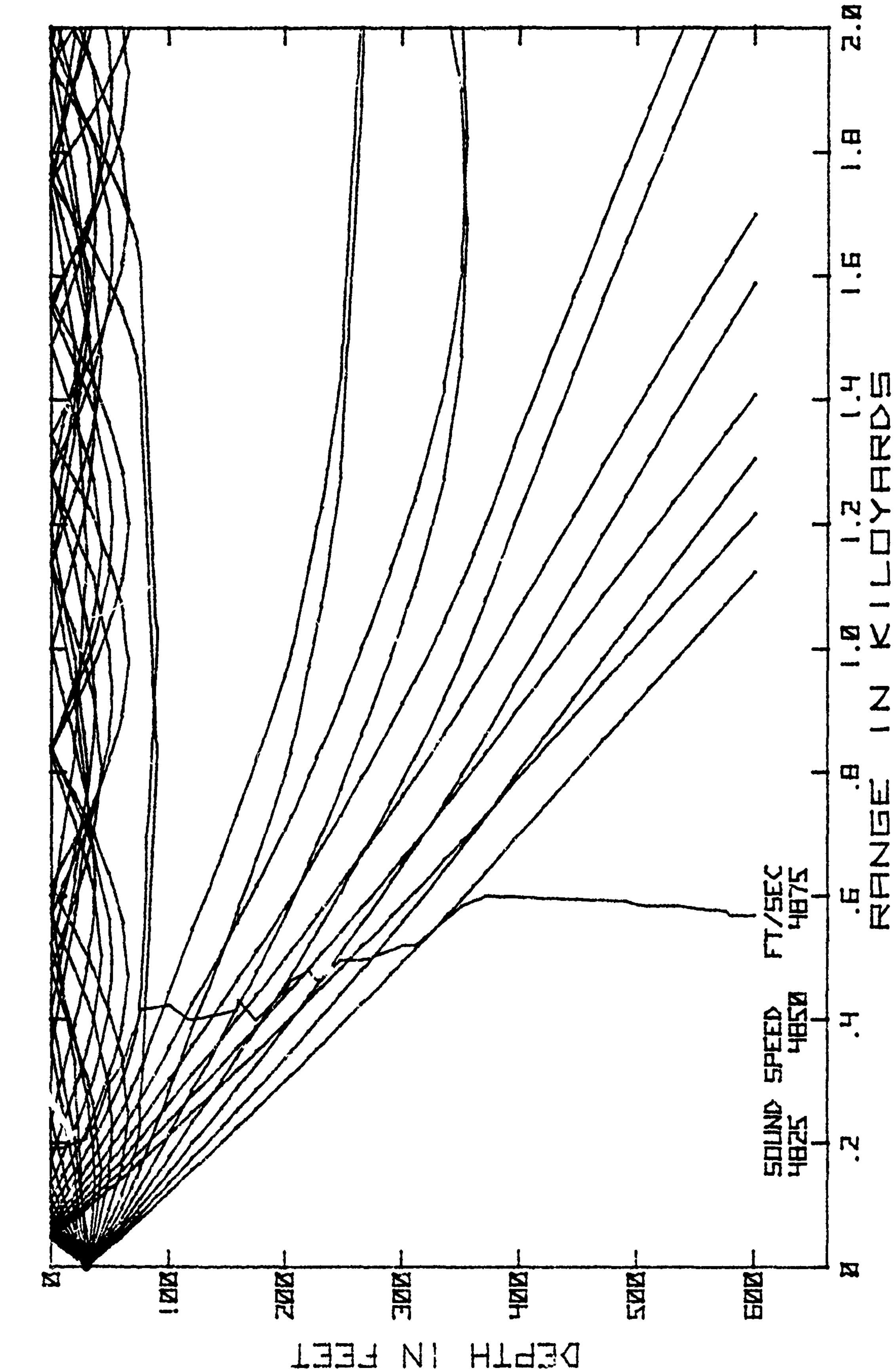

FIG. C-3. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 30 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

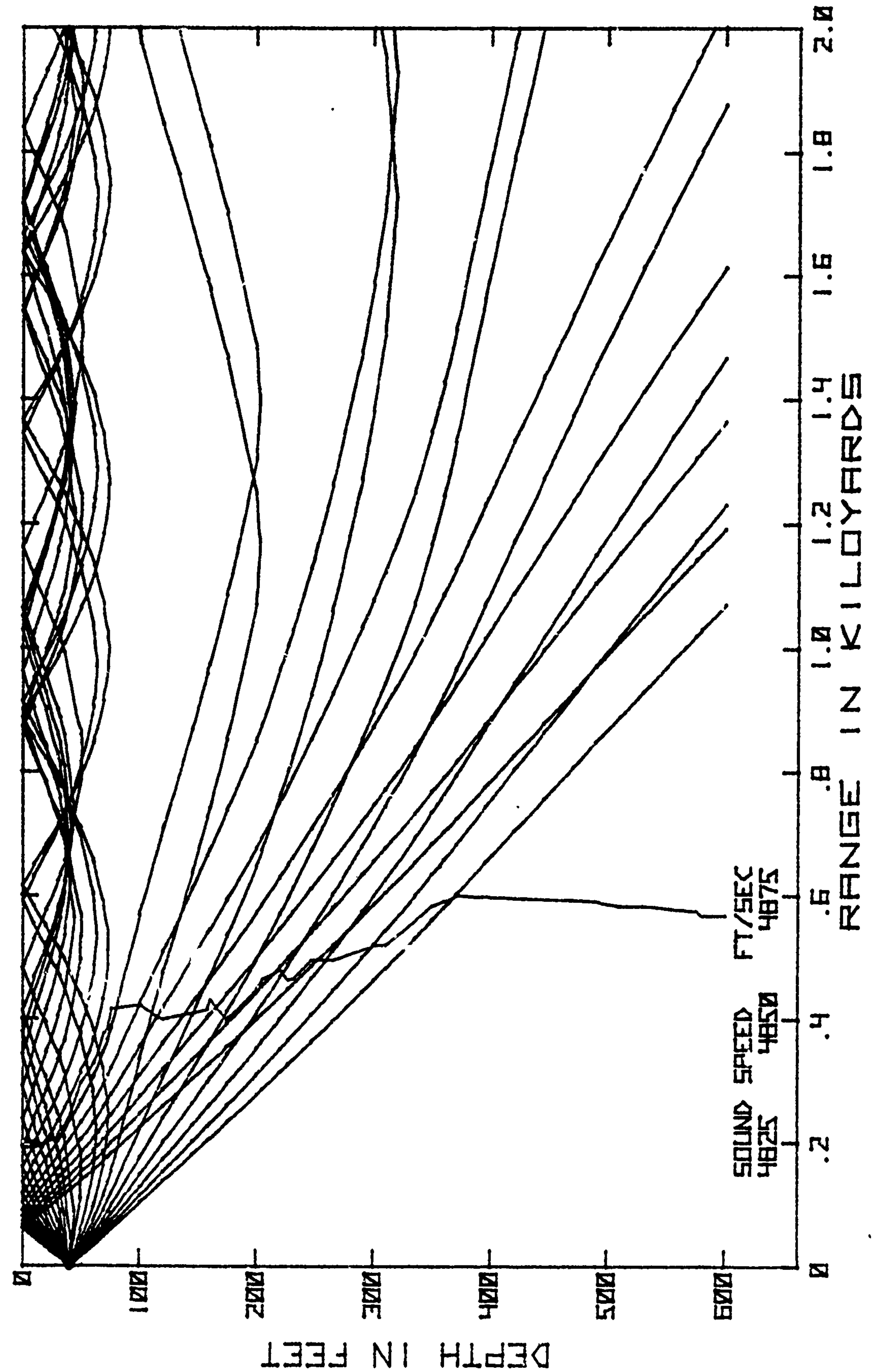

FIG. C-4. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 40 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

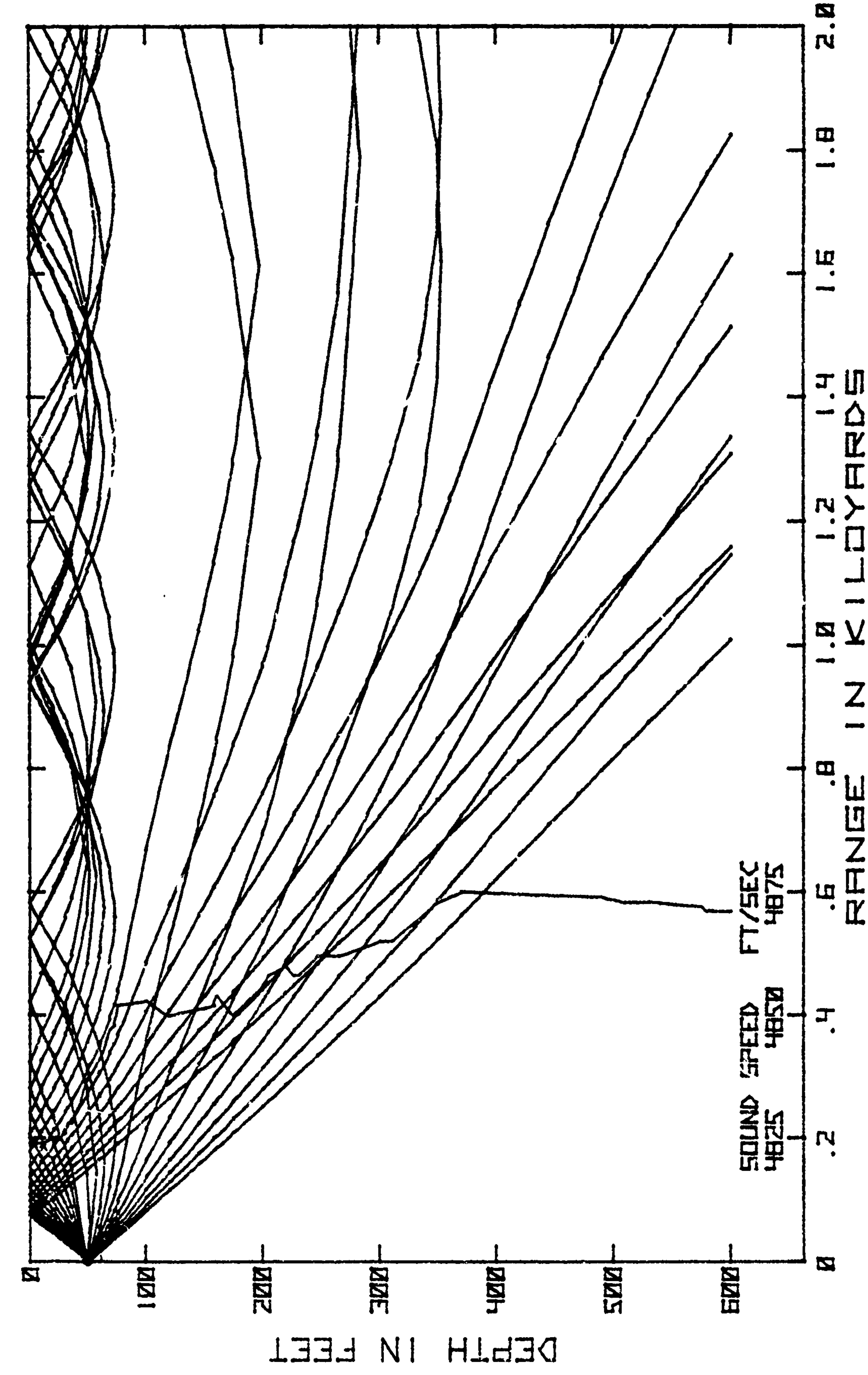

FIG. C-5. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 50 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

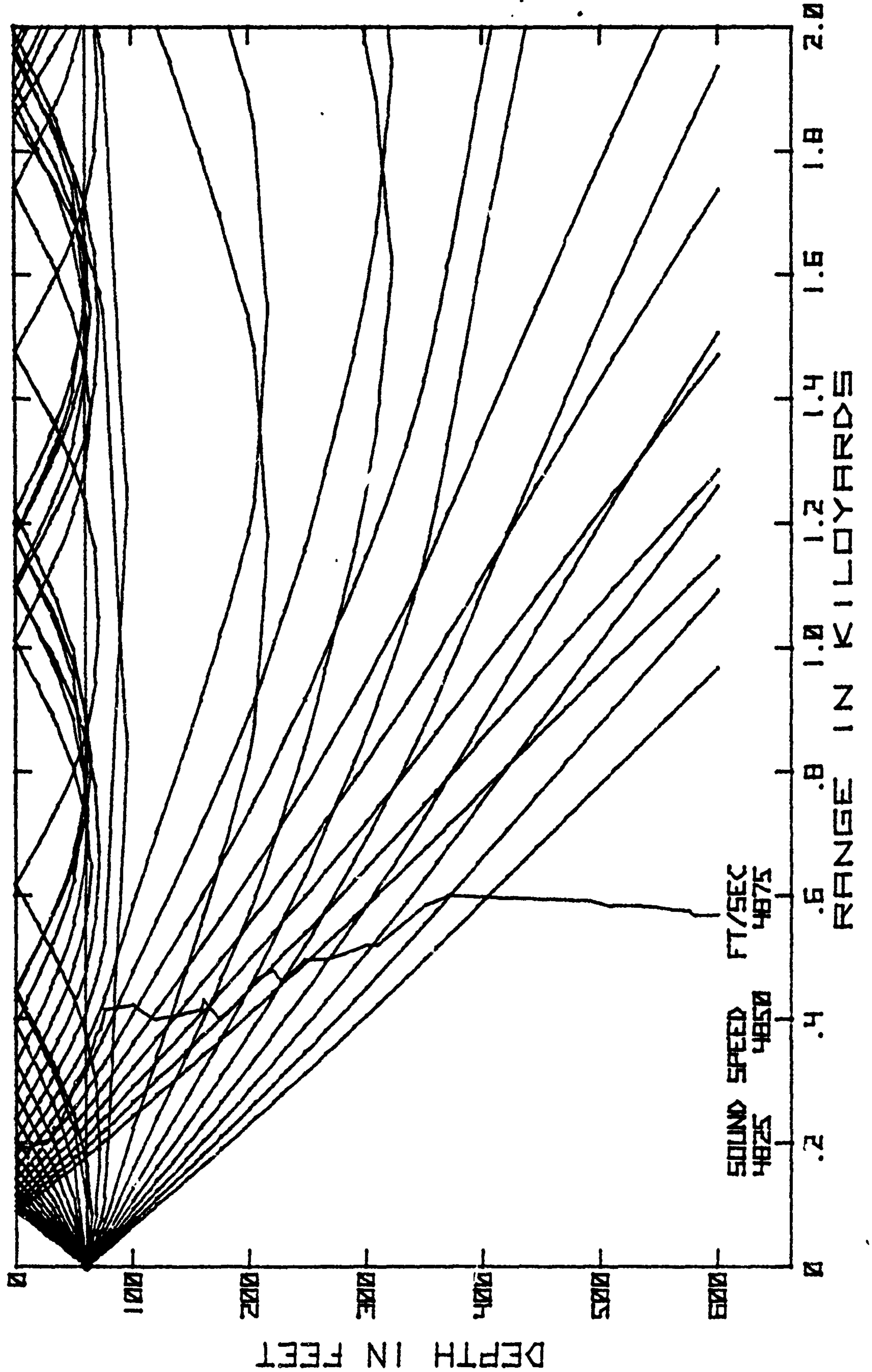

FIG. C-6. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 60 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

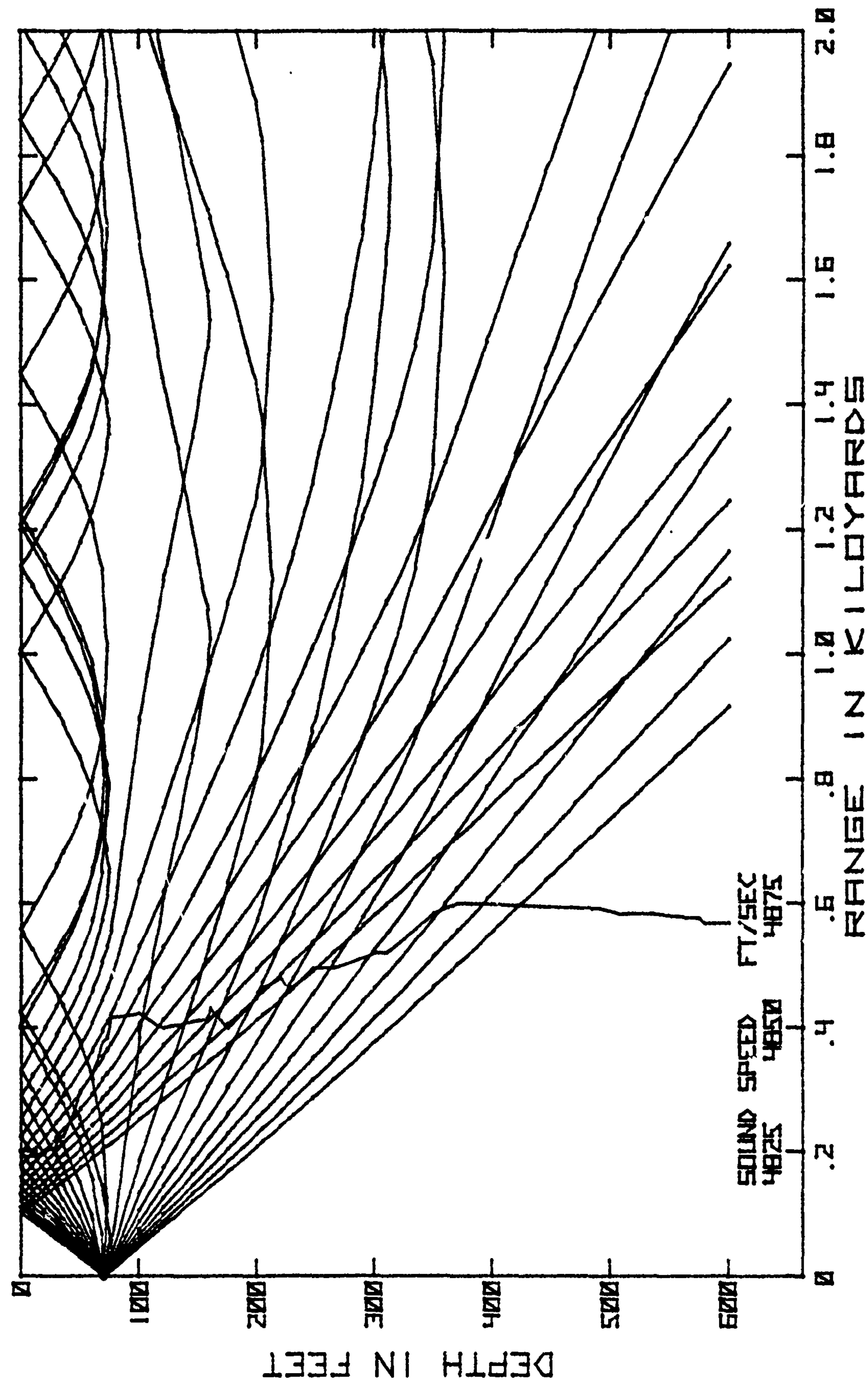

FIG. C-7. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 70 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

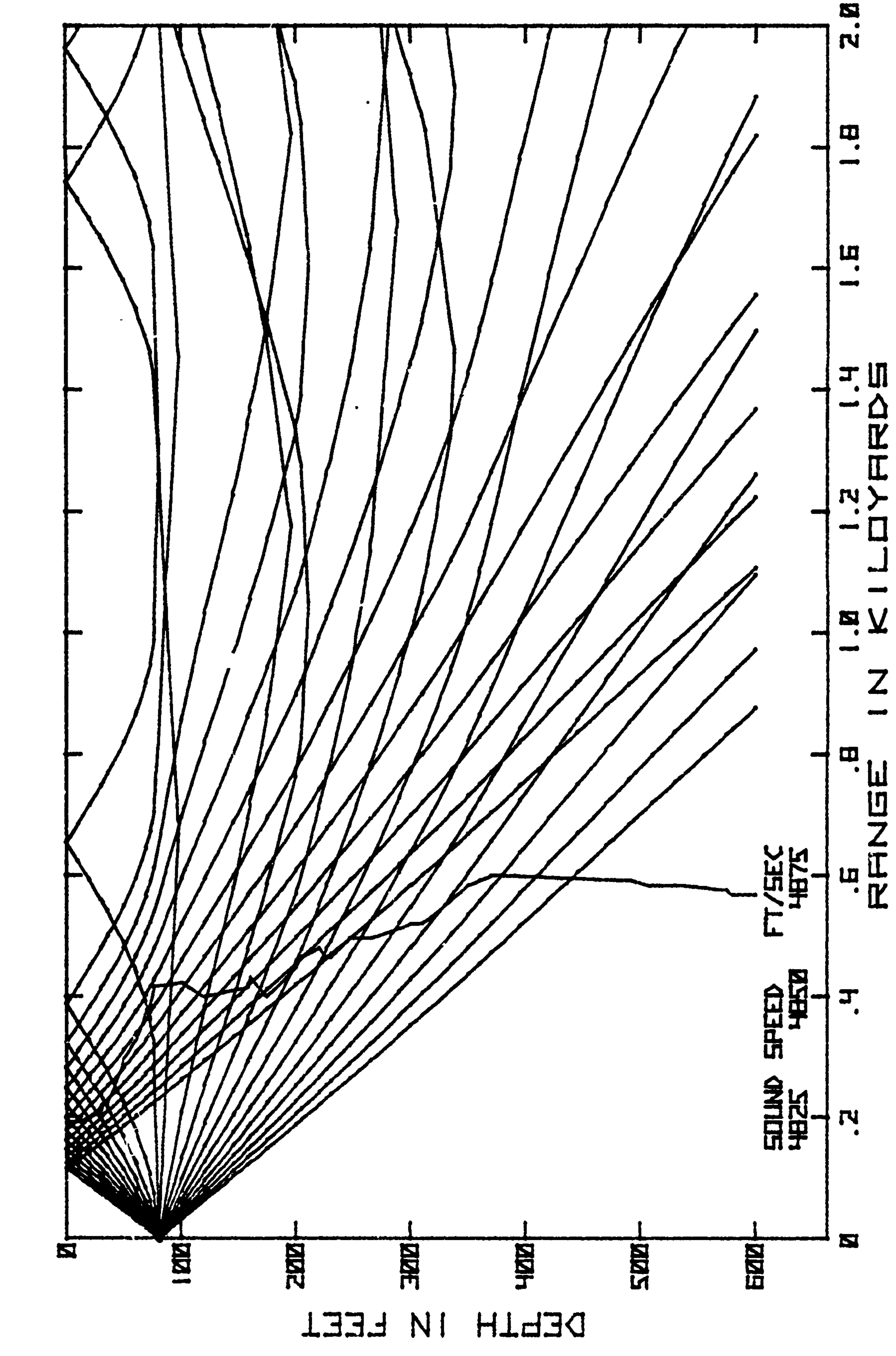

FIG. C-8. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 80 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

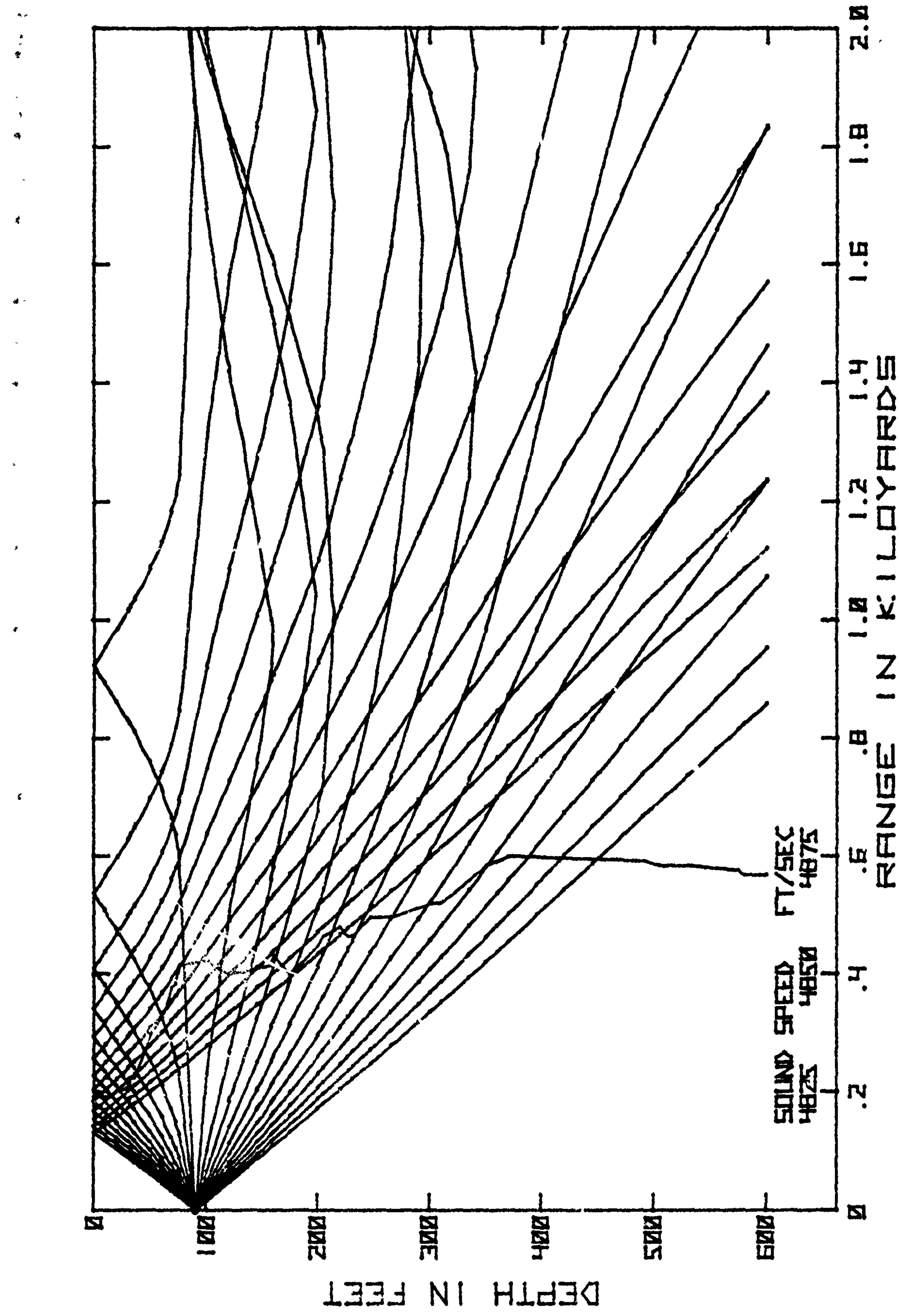

FIG. C-9. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 90 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

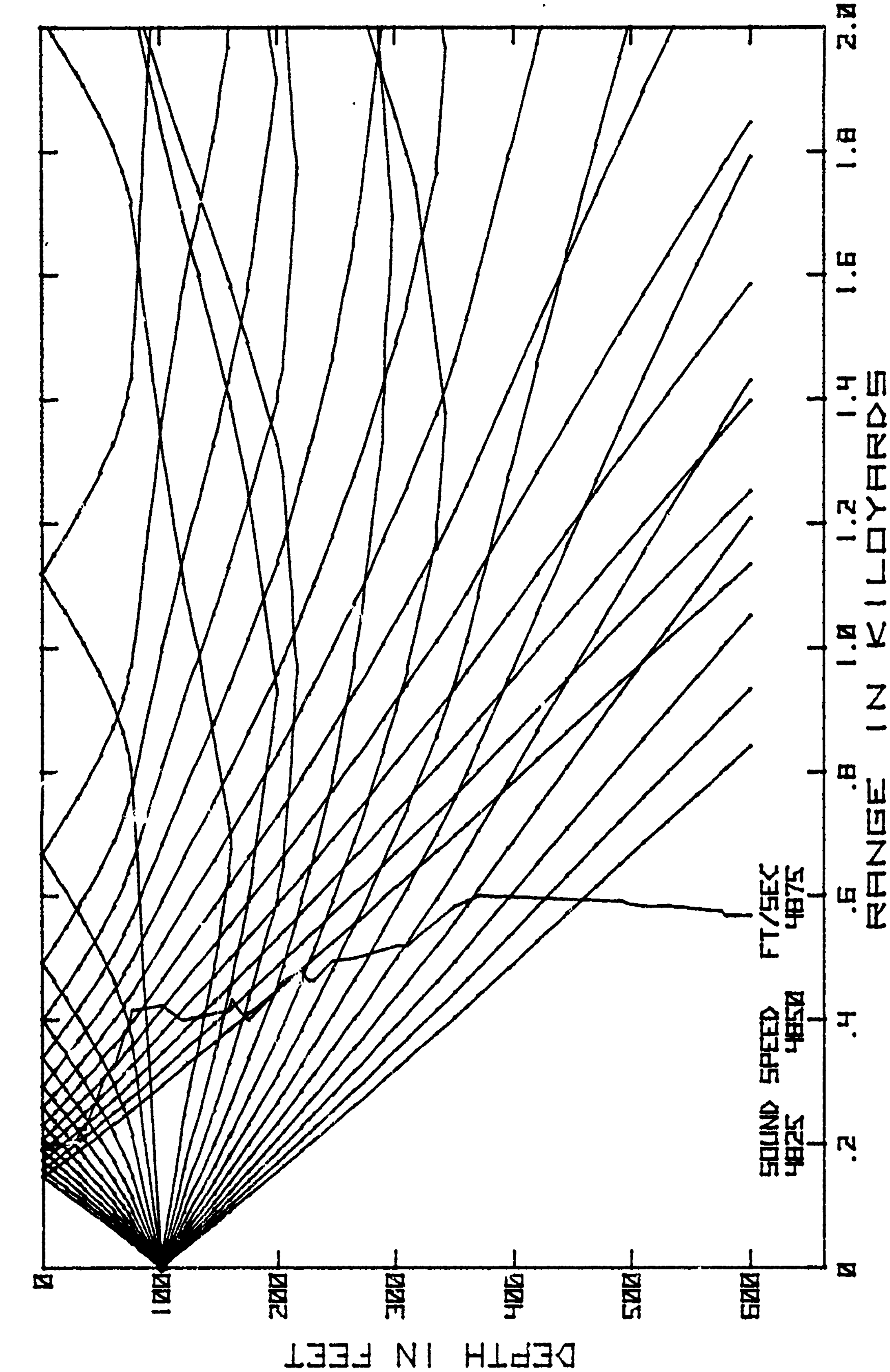

FIG. C-10. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 100 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

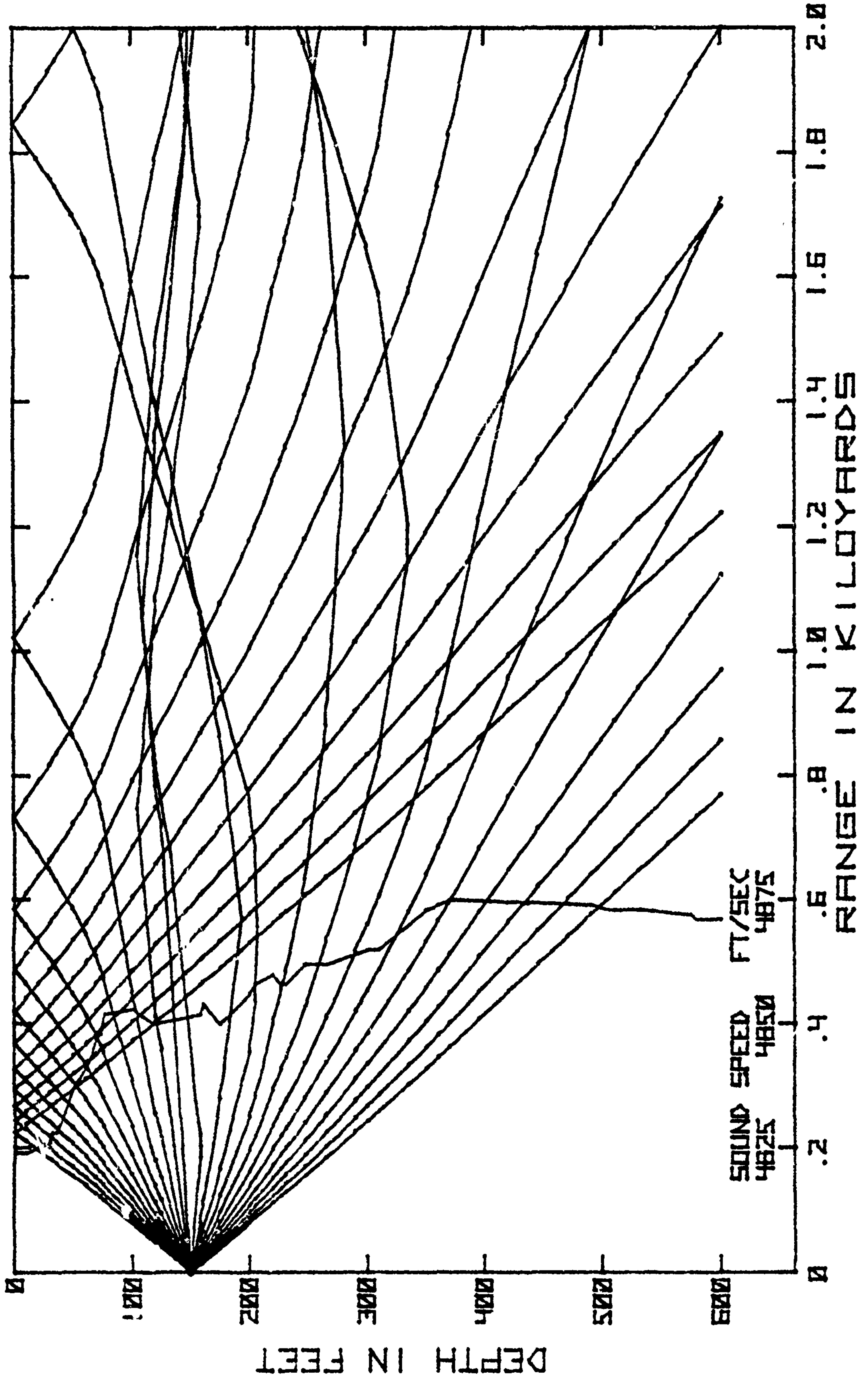

FIG. C-11. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 150 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

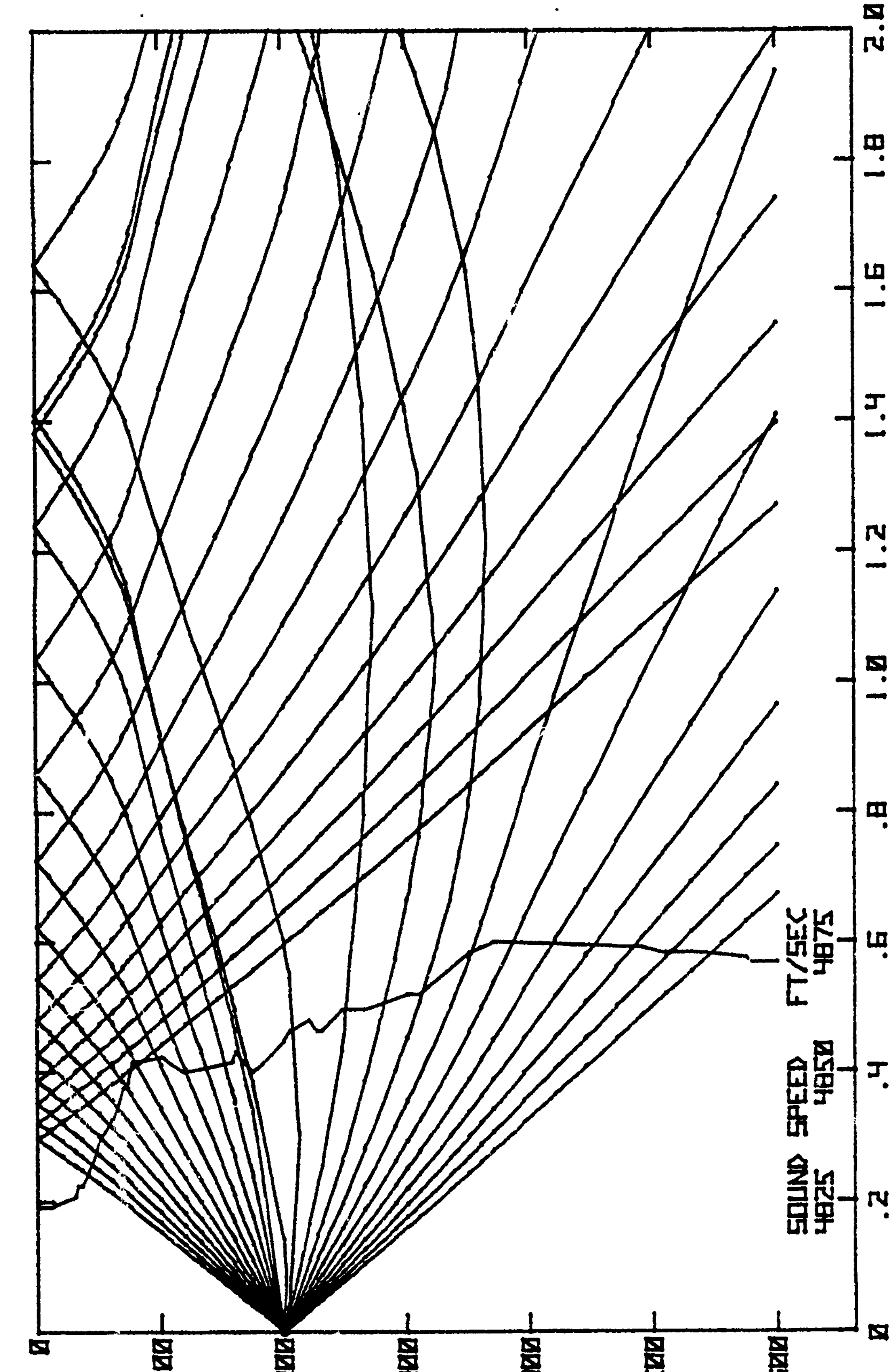

FIG. C-12. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 200 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

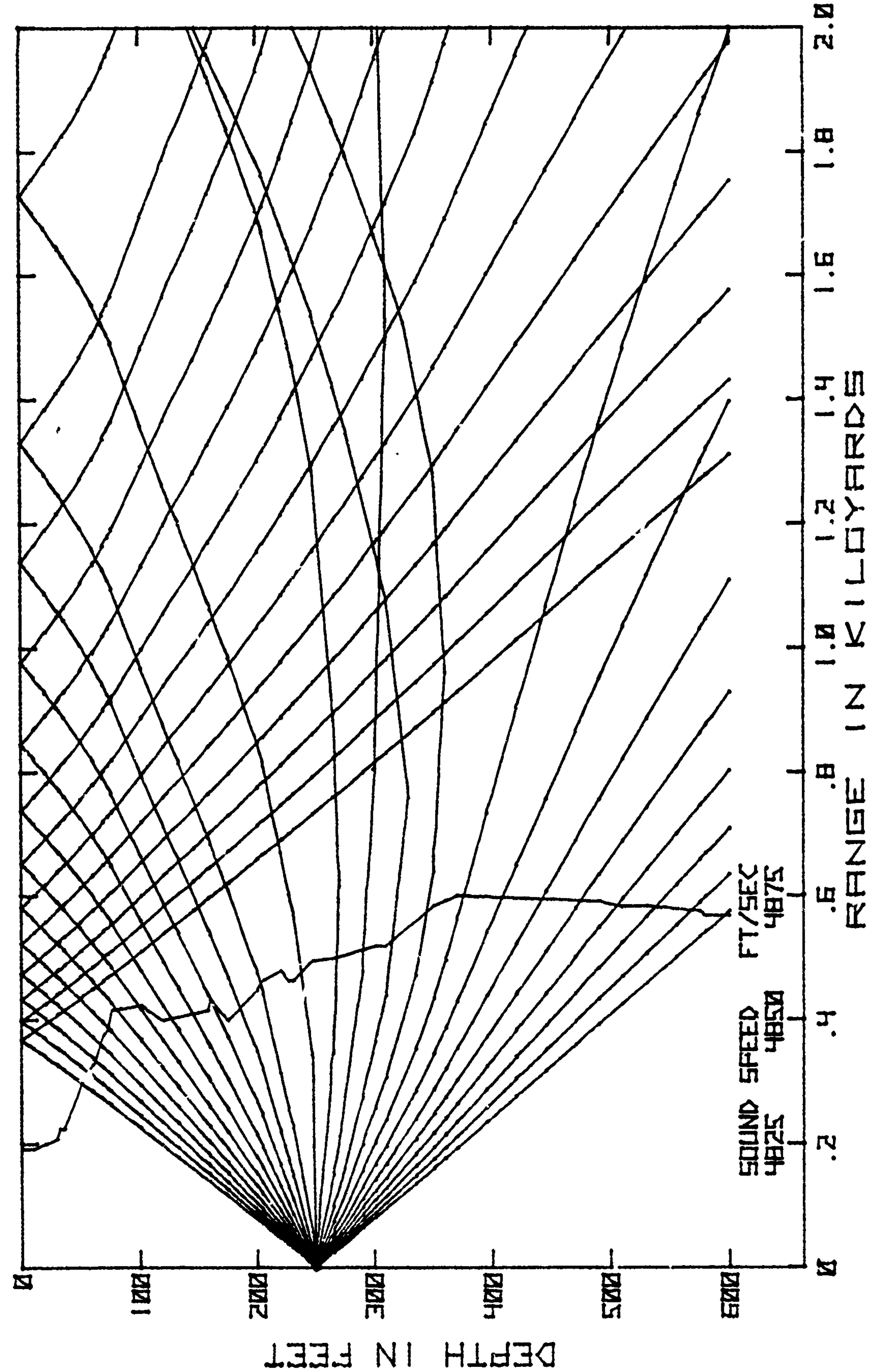

FIG. C-13. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 250 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

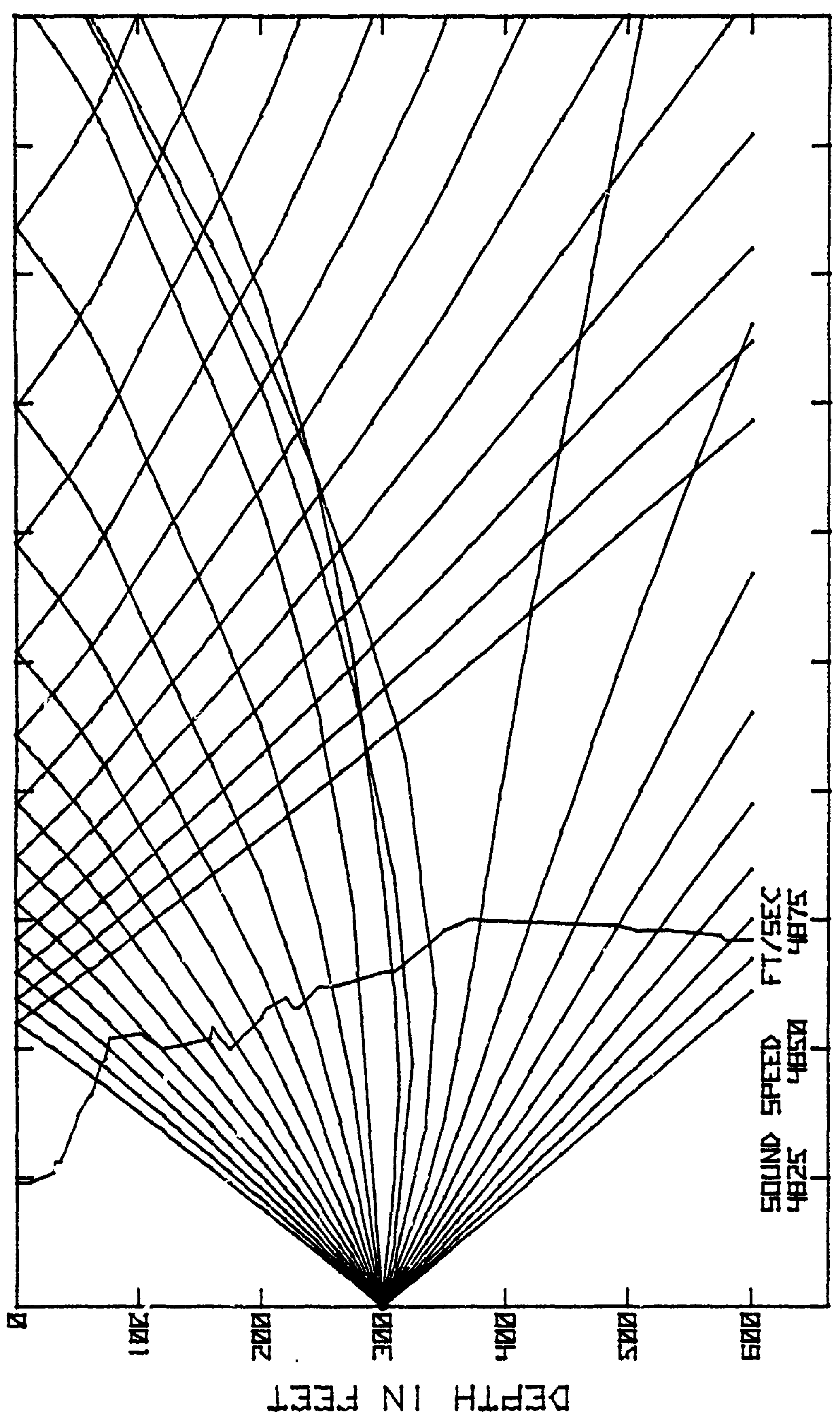

FIG. C-14: RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 300 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

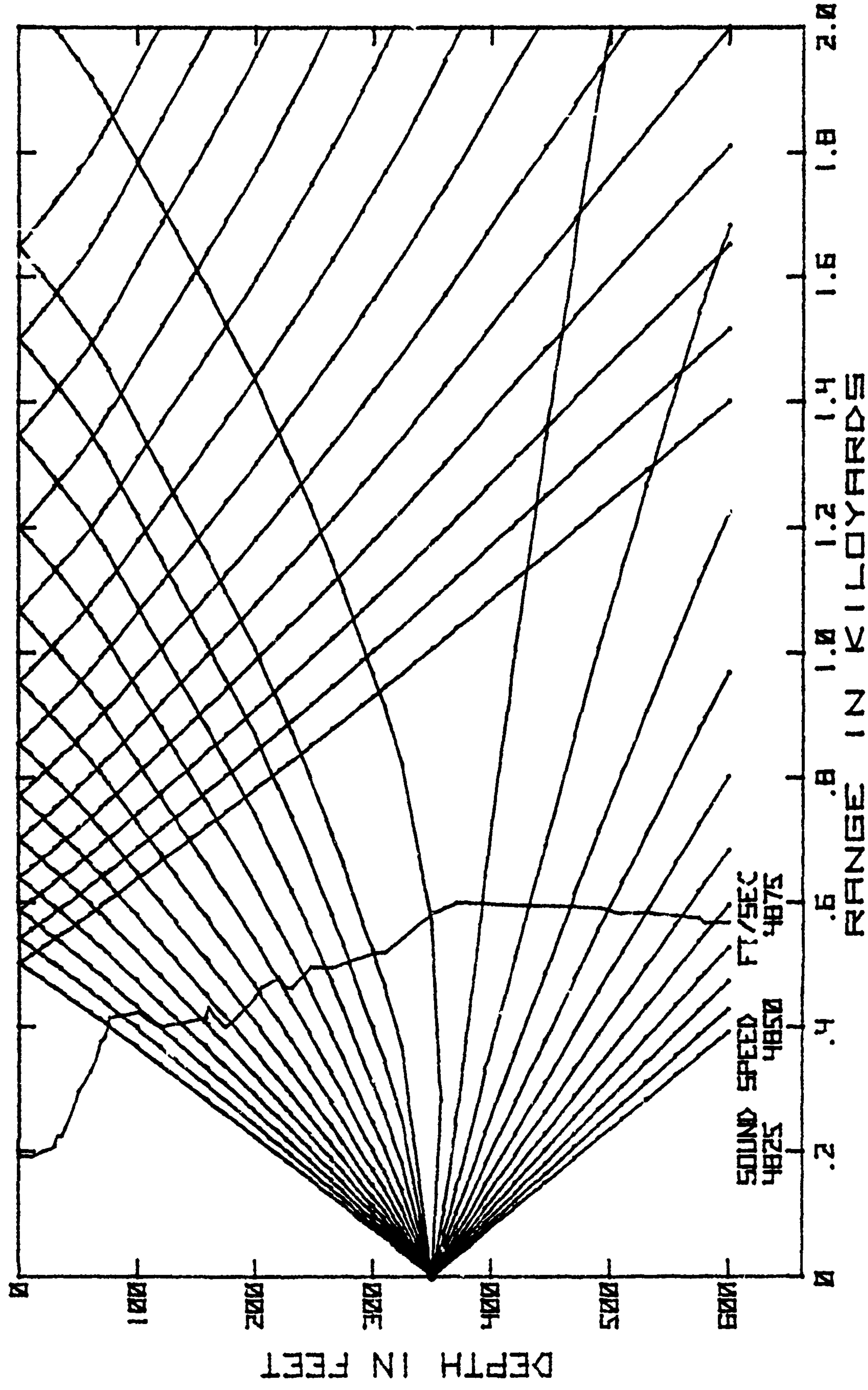

FIG. C-15. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 35Ø FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

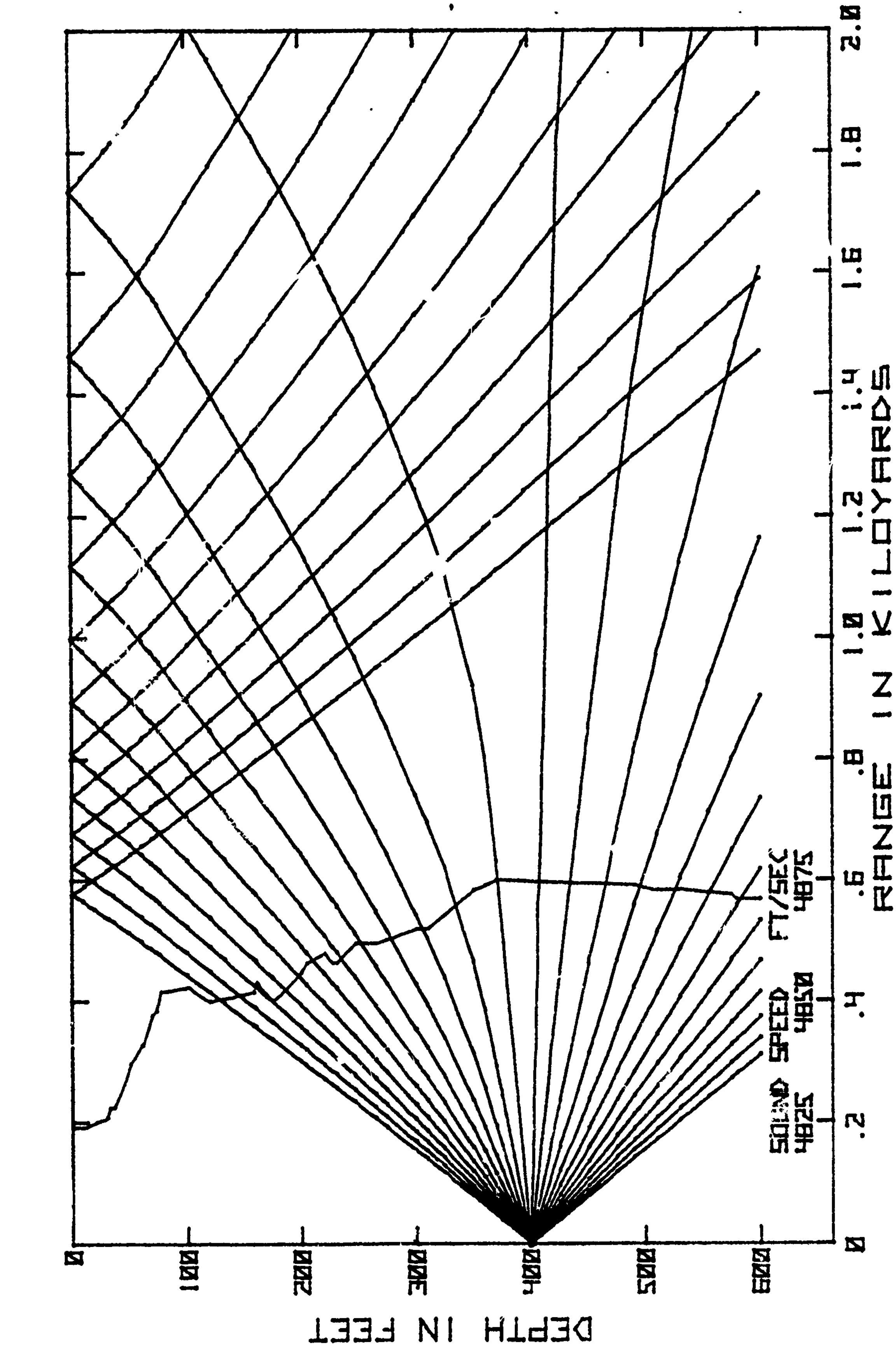

FIG. C-16. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 400 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

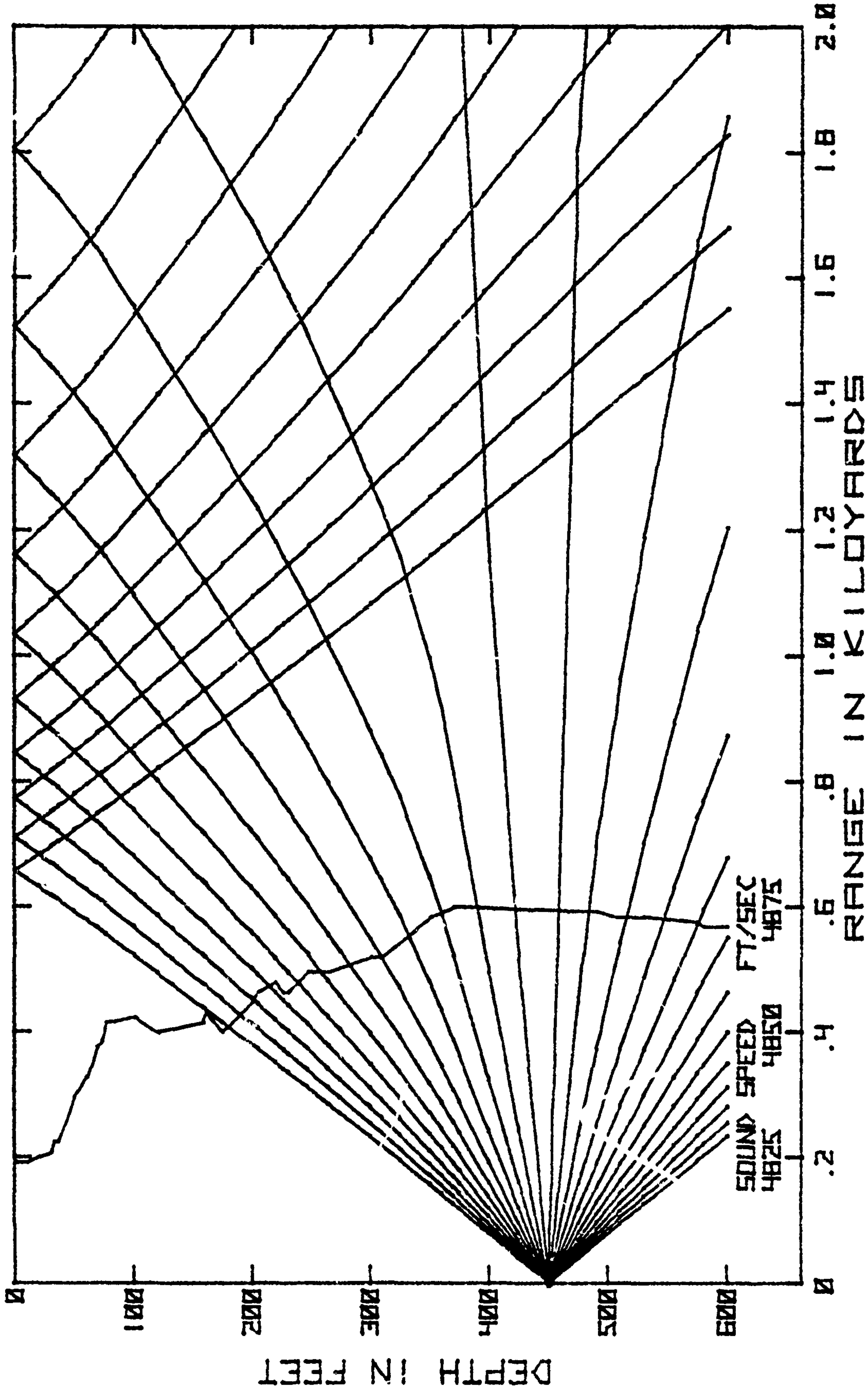

FIG. C-17. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 450 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

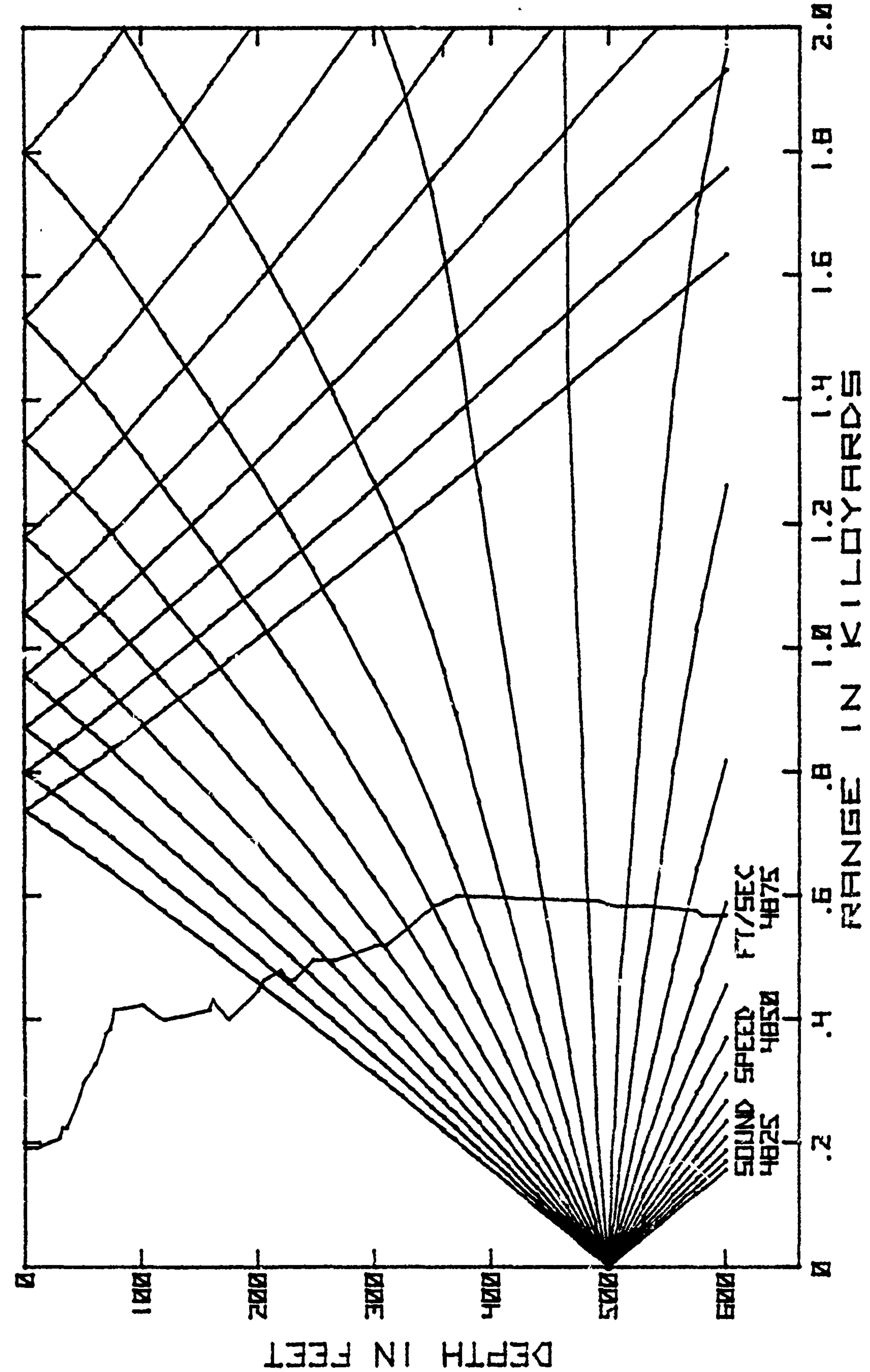

FIG. C-18. RAY DIAGRAM FOR FEBRUARY SOURCE DEPTH 500 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

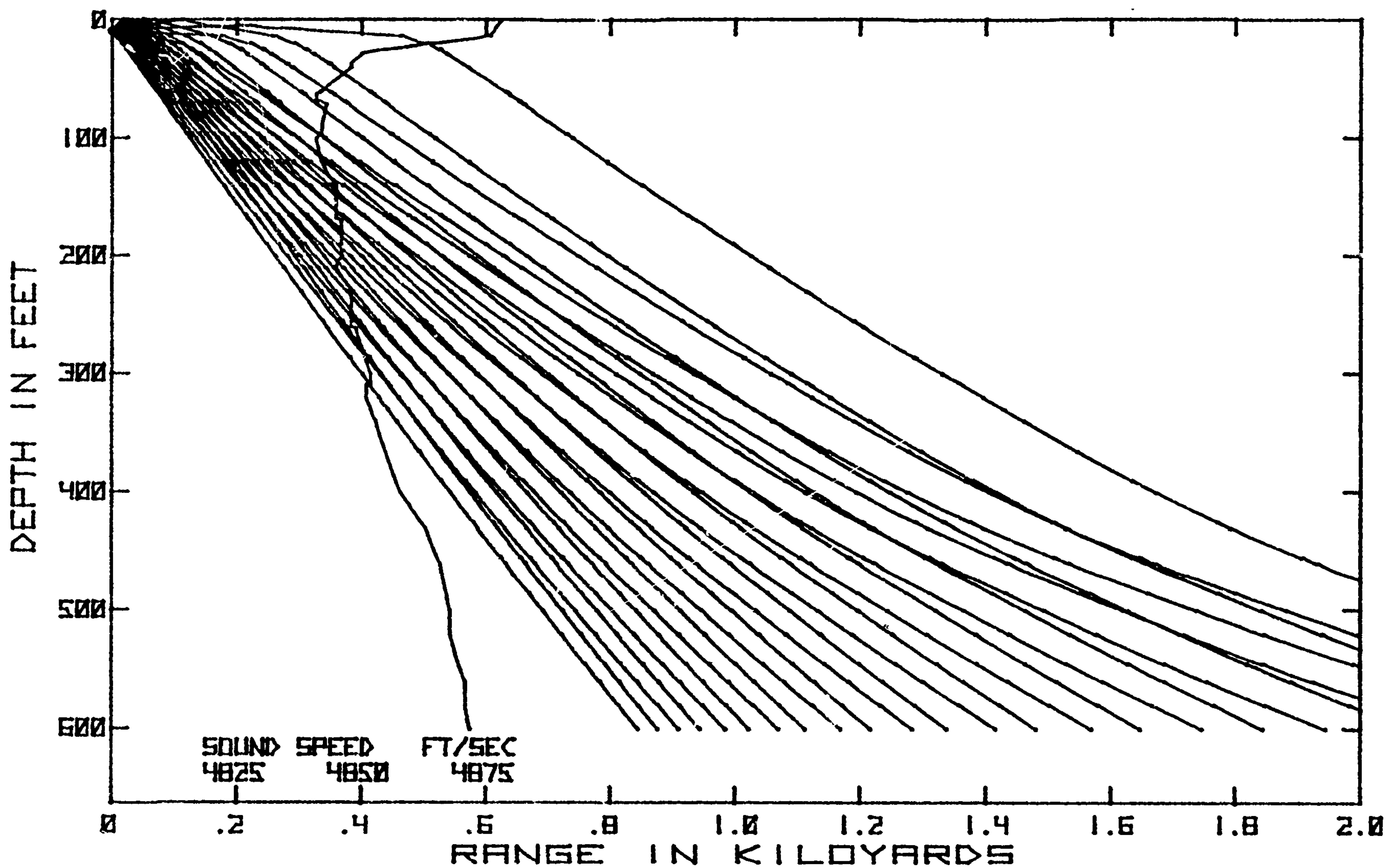

FIG. C-19. RAY DIAGRAM FOR APRIL SOURCE DEPTH 10 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

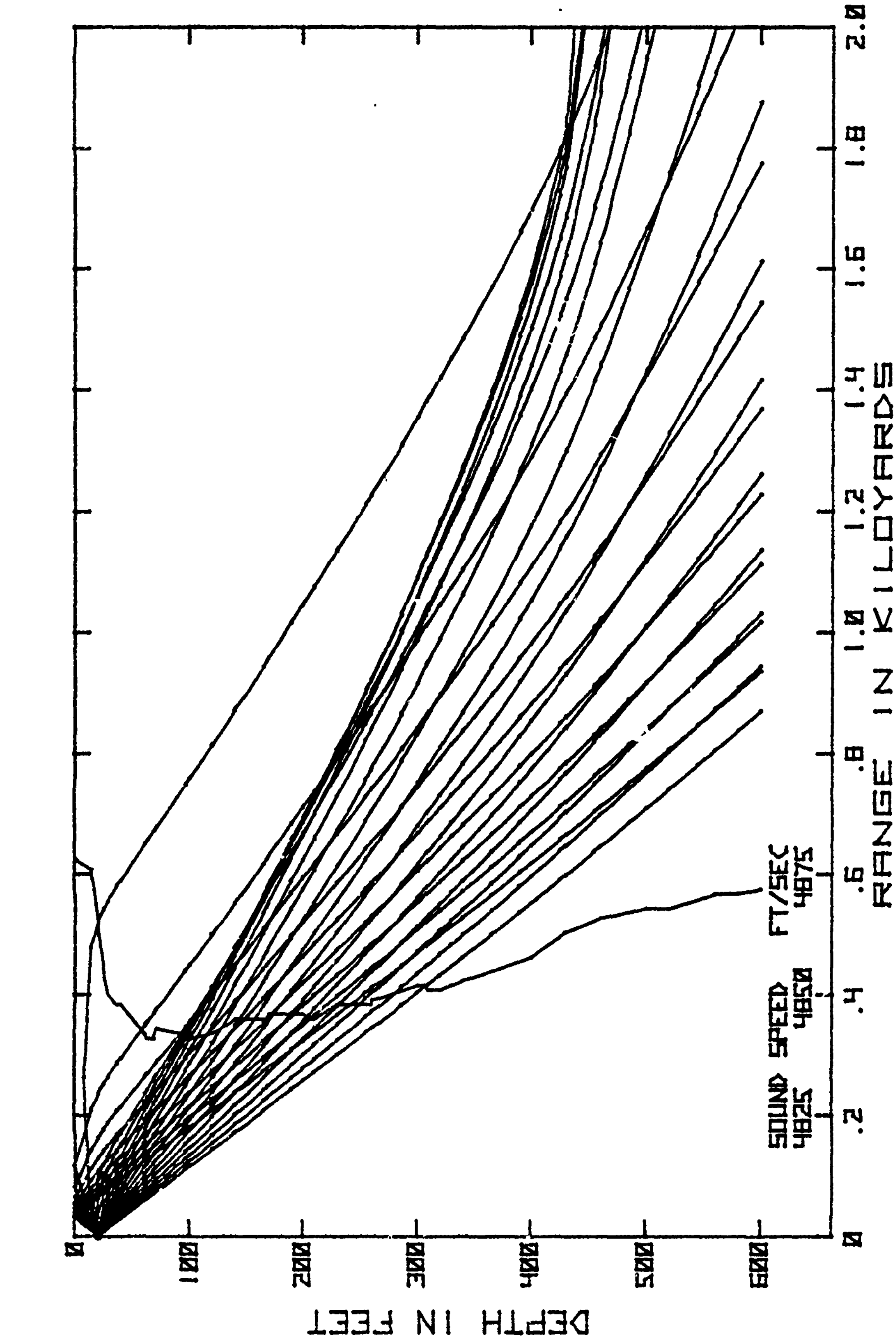

FIG. C-20. RAY DIAGRAM FOR APRIL SOURCE DEPTH 20 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

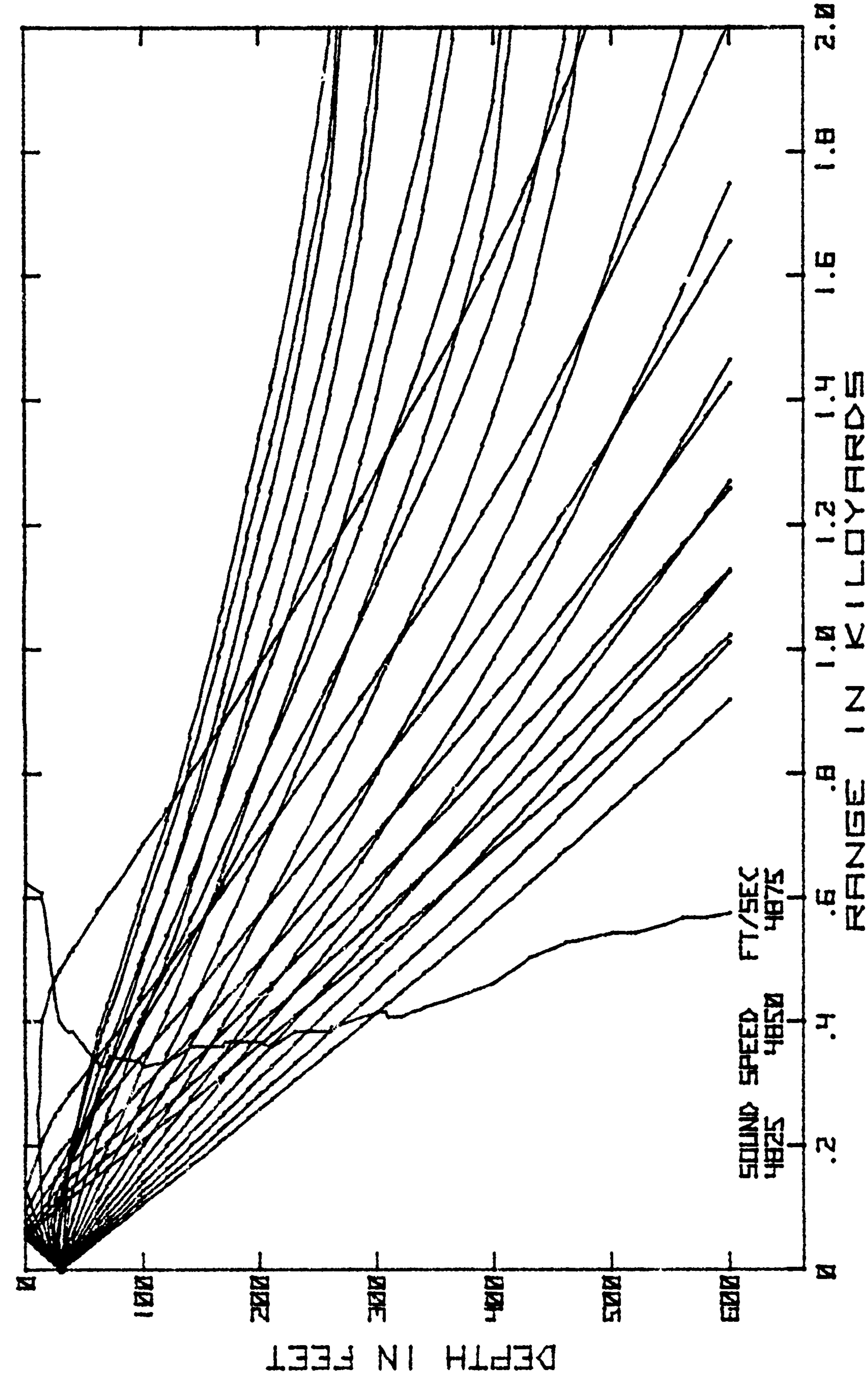

FIG. C-21. RAY DIAGRAM FOR APRIL SOURCE DEPTH 3Ø FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

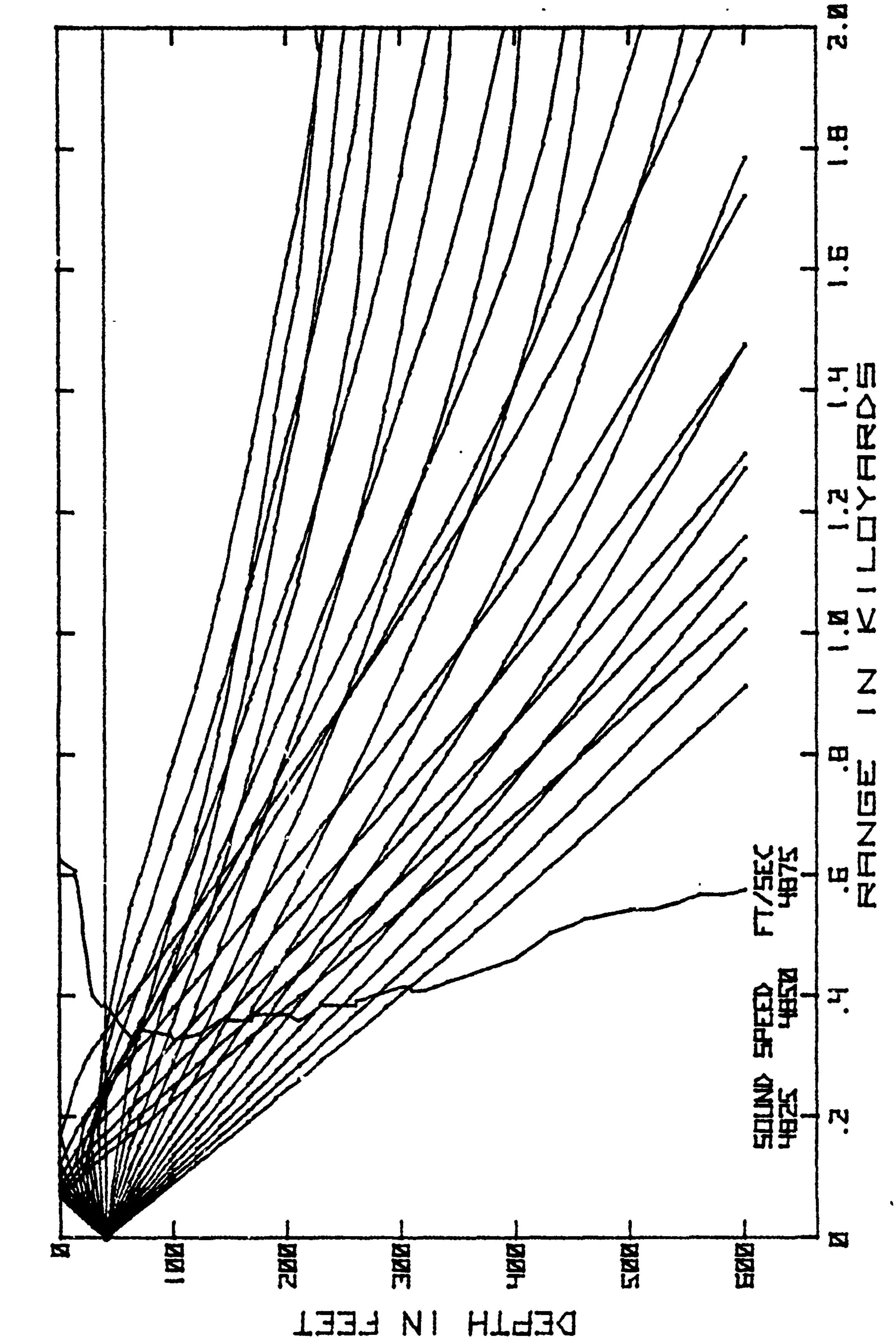

FIG. C-22. RAY DIAGRAM FOR APRIL SOURCE DEPTH 40 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

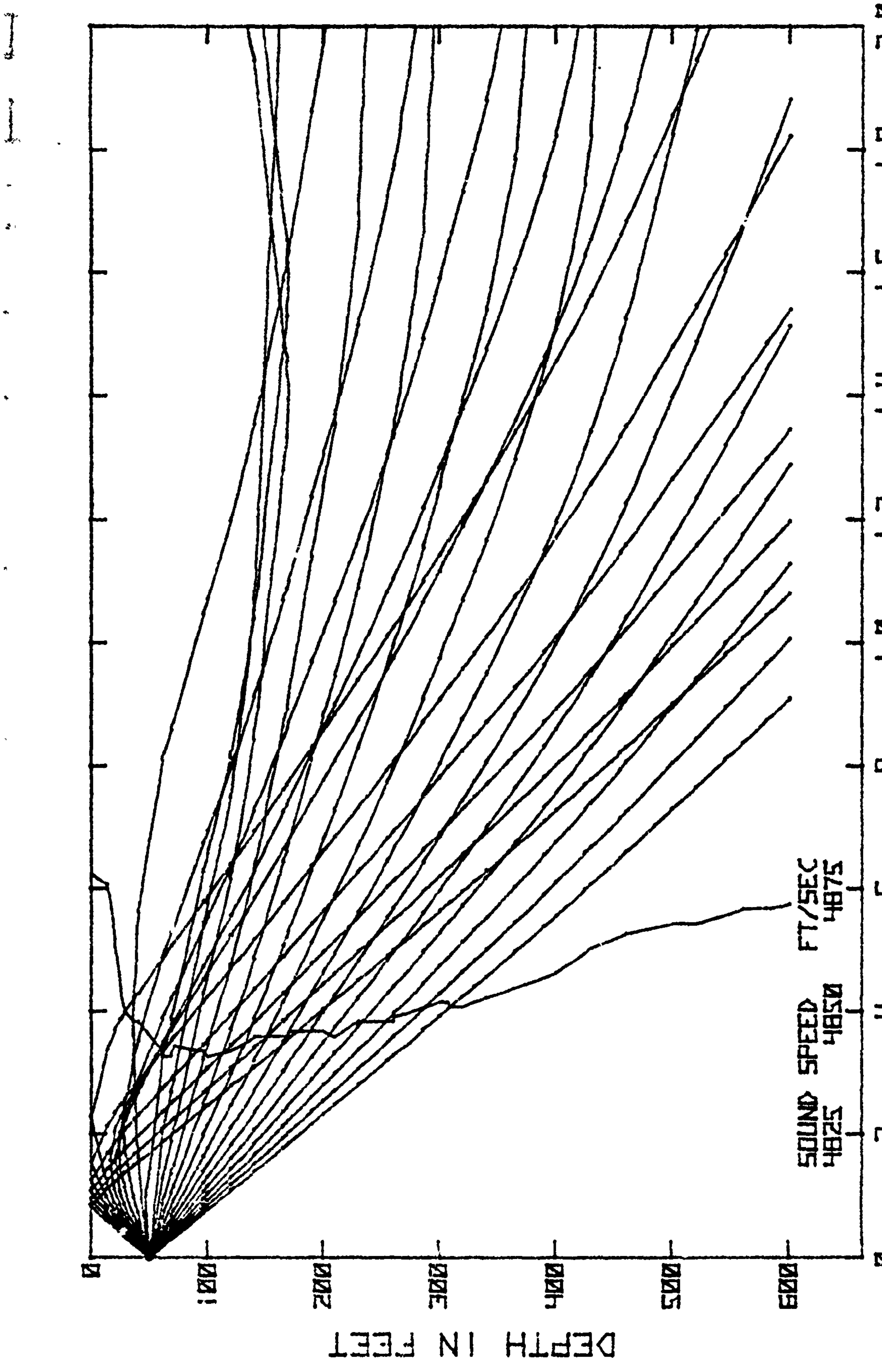

FIG. C-23. RAY DIAGRAM FOR APRIL SOURCE DEPTH 50 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

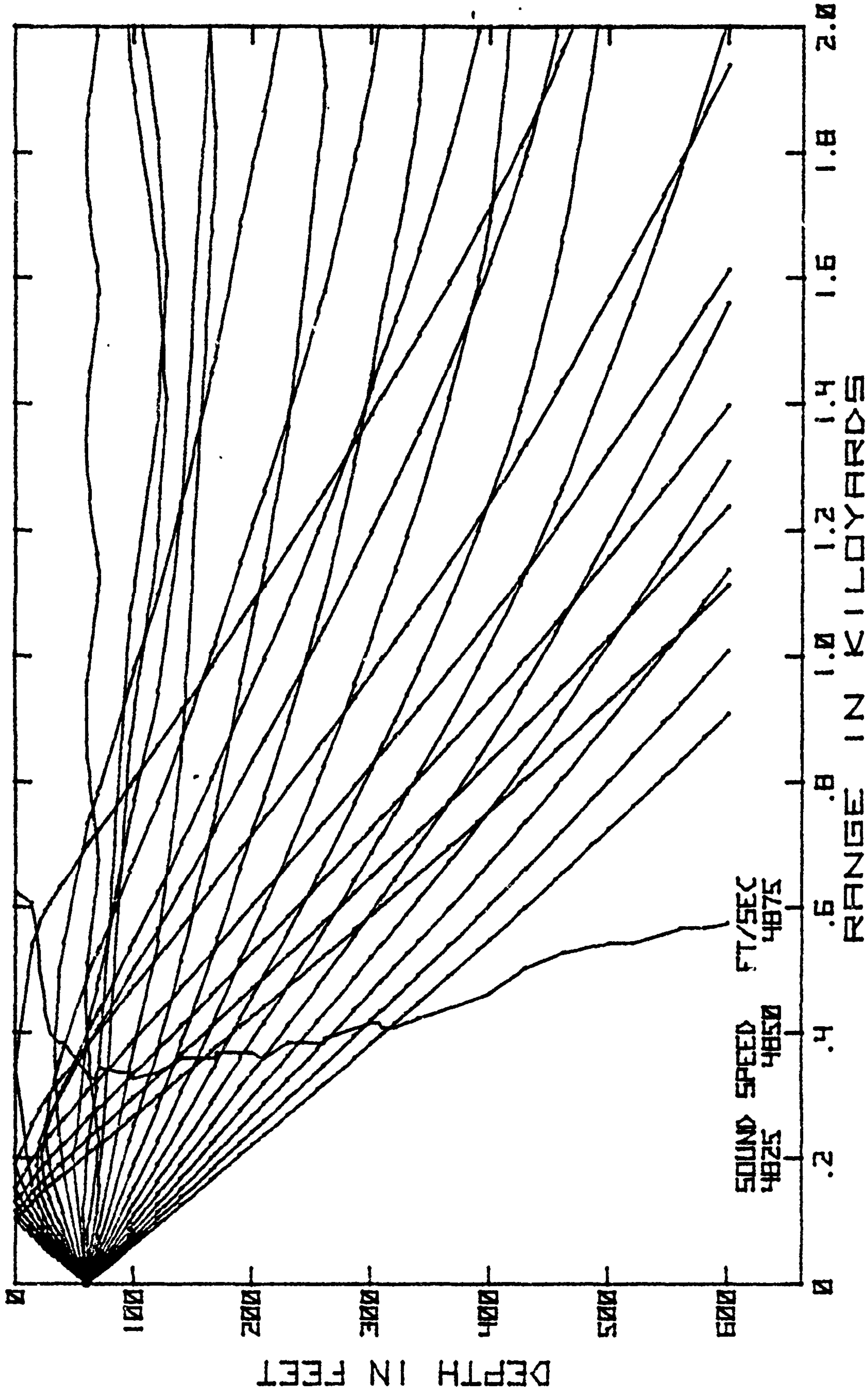

FIG. C-24. RAY DIAGRAM FOR APRIL SOURCE DEPTH 60 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

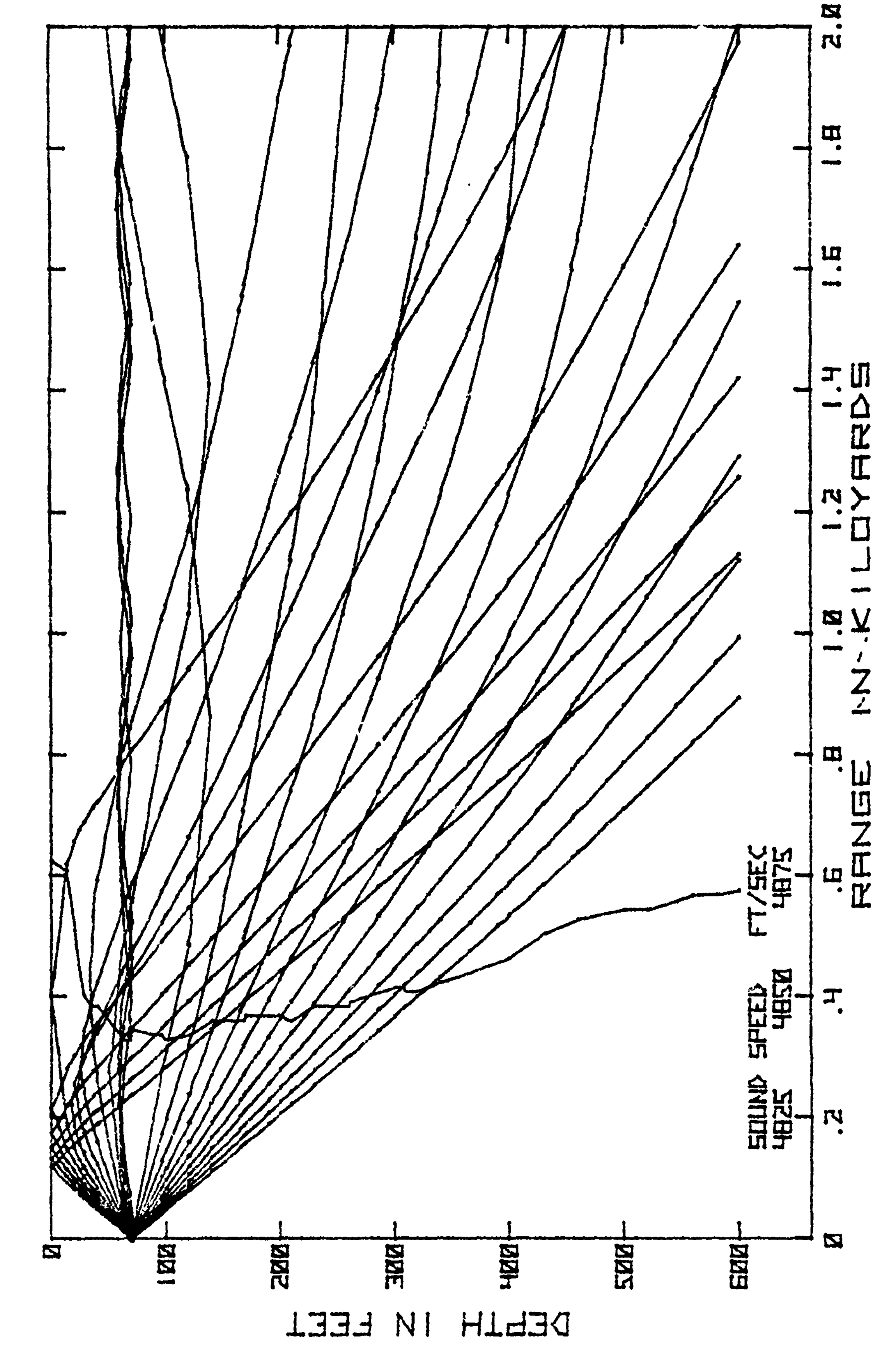

FIG. C-25. RAY DIAGRAM FOR APRIL SOURCE DEPTH 70 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

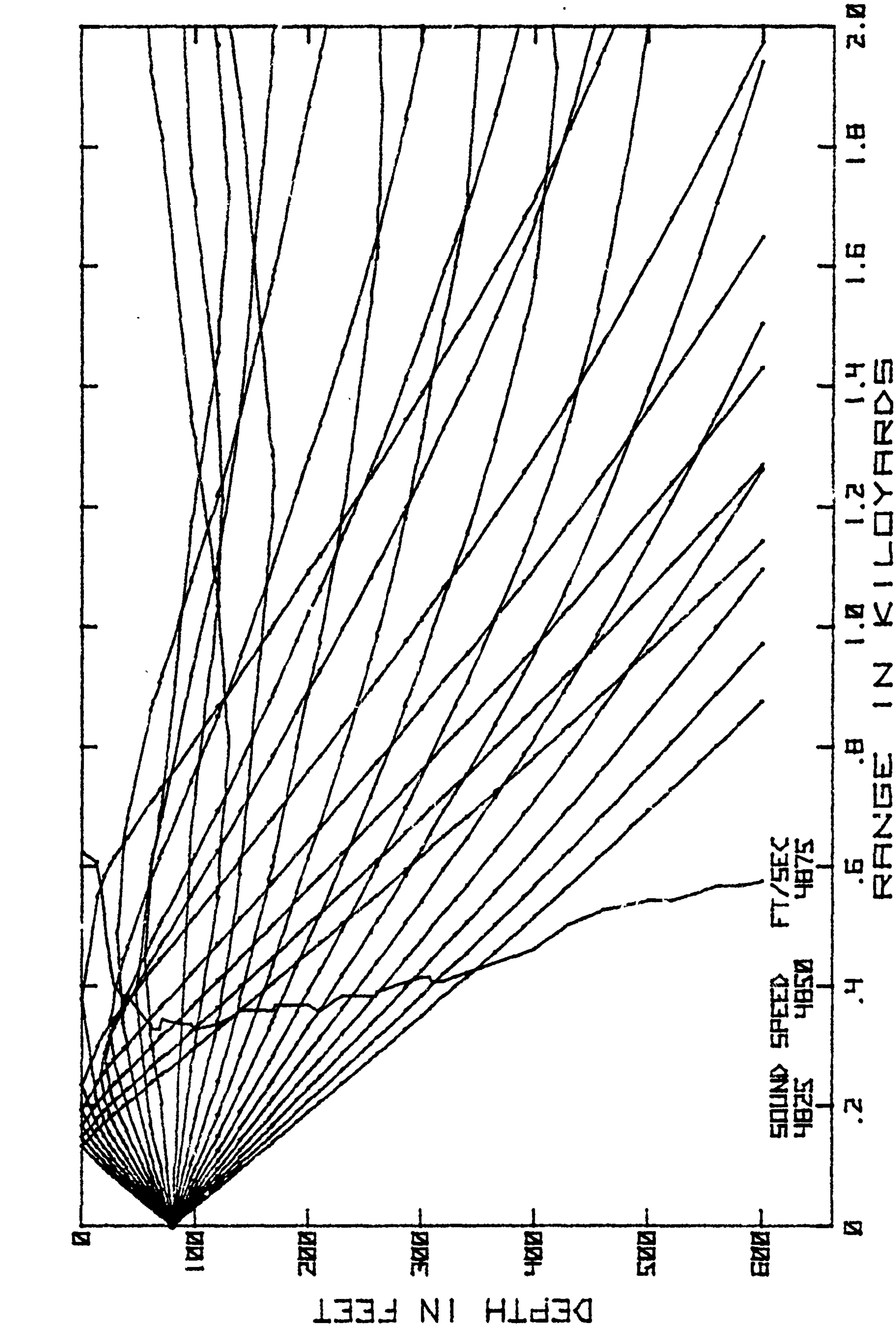

FIG. C-26. RAY DIAGRAM FOR APRIL SOURCE DEPTH 80 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

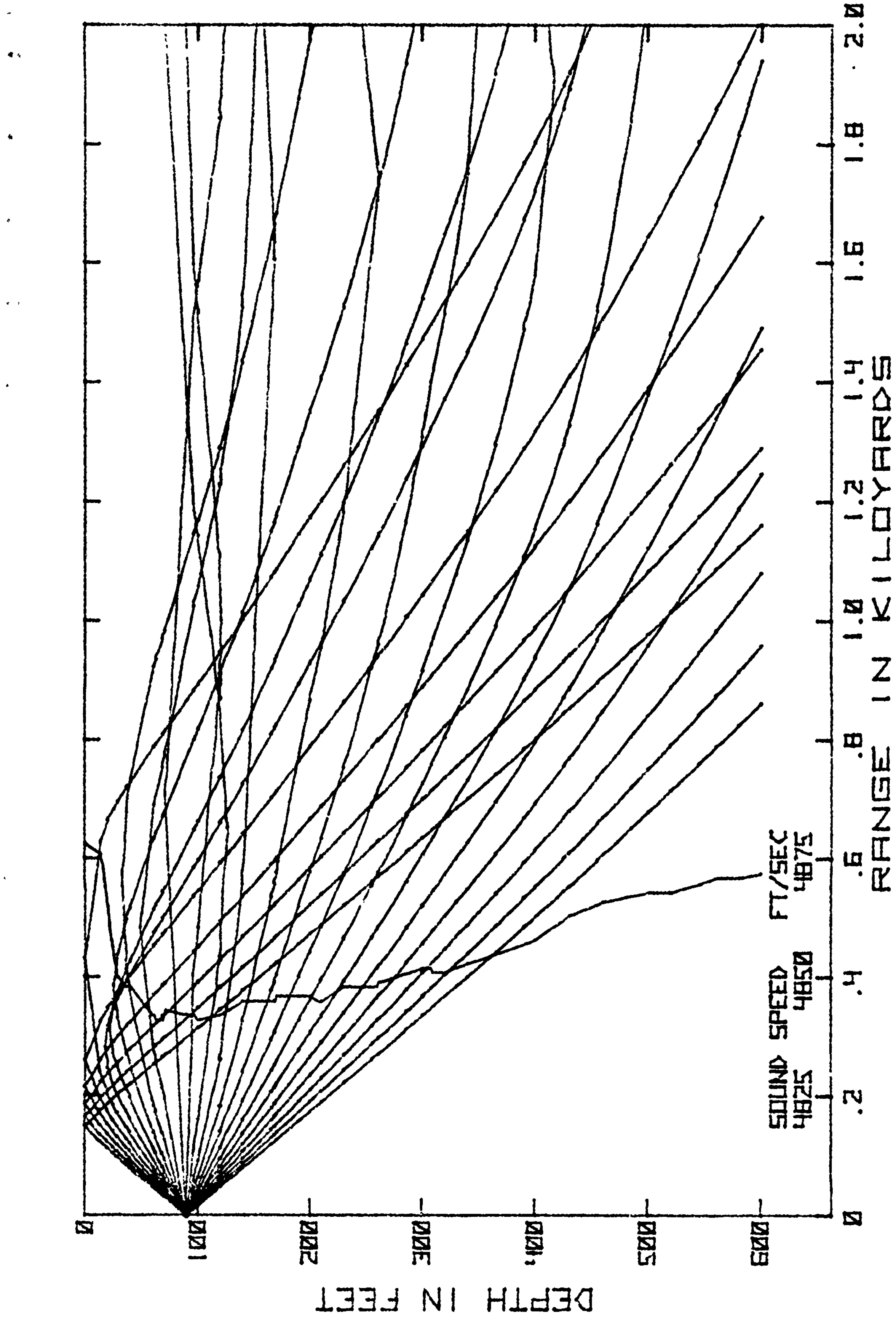

FIG. C-27. RAY DIAGRAM FOR APRIL SOURCE DEPTH 90 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

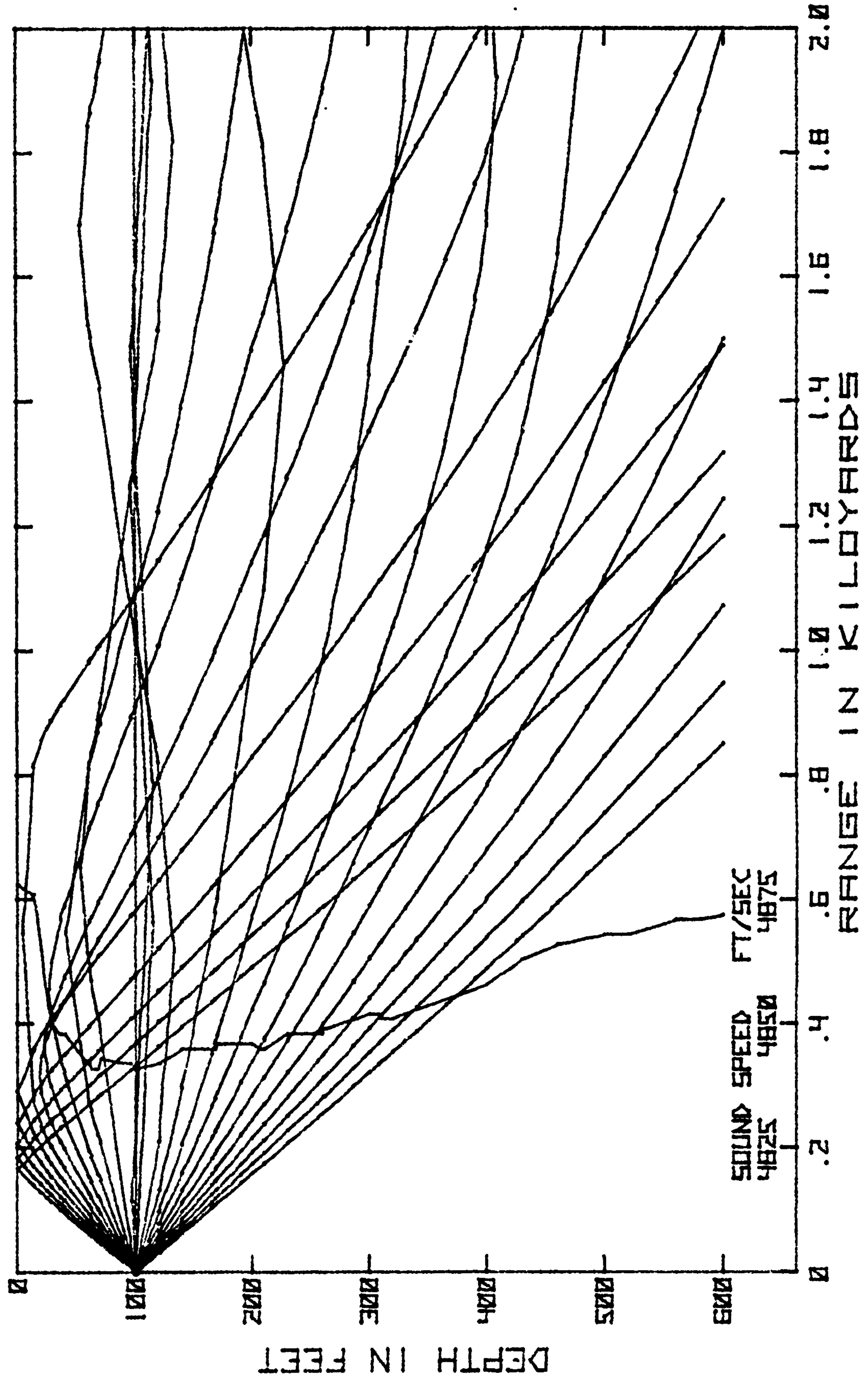

FIG. C-28. RAY DIAGRAM FOR APRIL SOURCE DEPTH 100 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

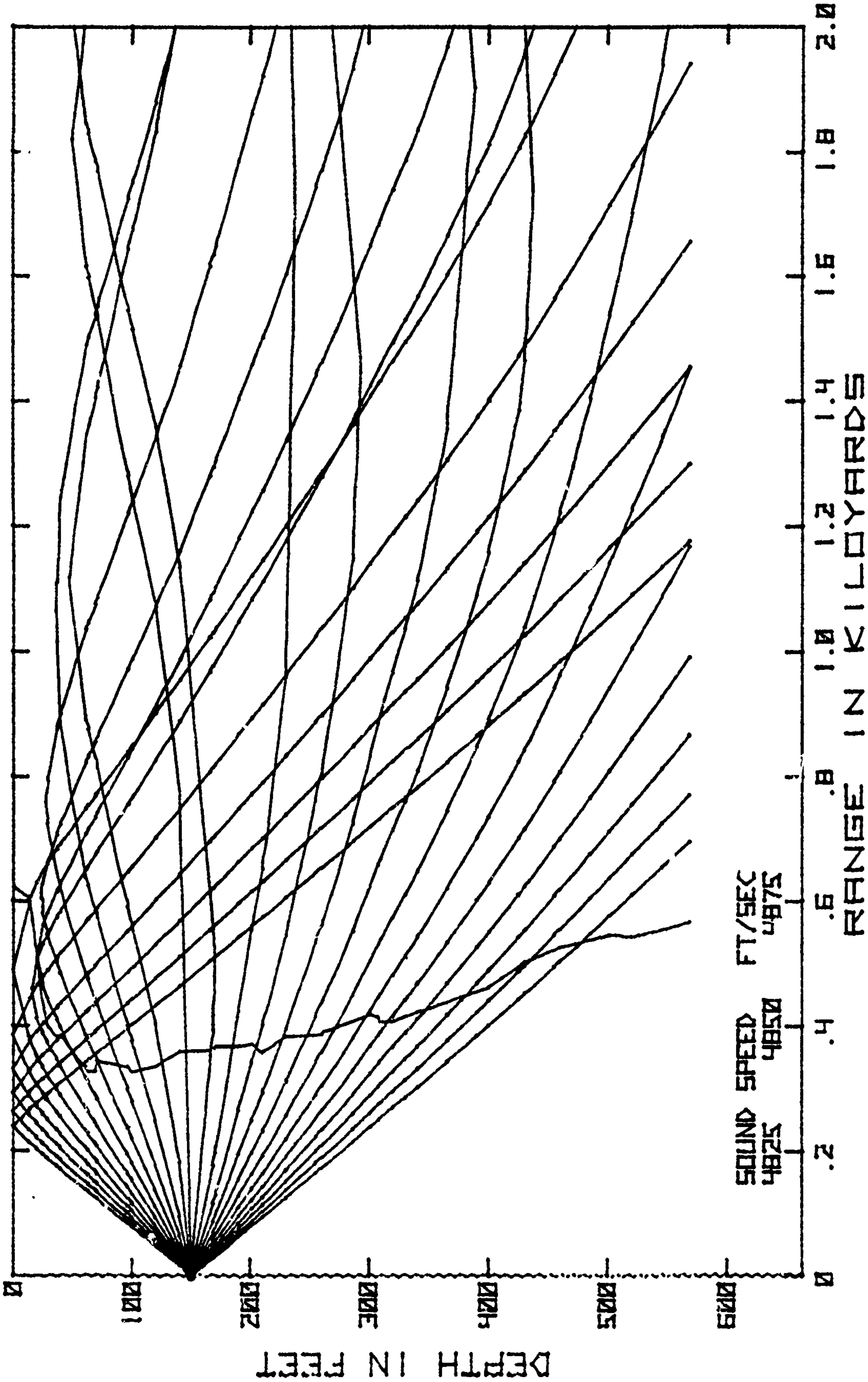

FIG. C-29. RAY DIAGRAM FOR APRIL SOURCE DEPTH 150 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

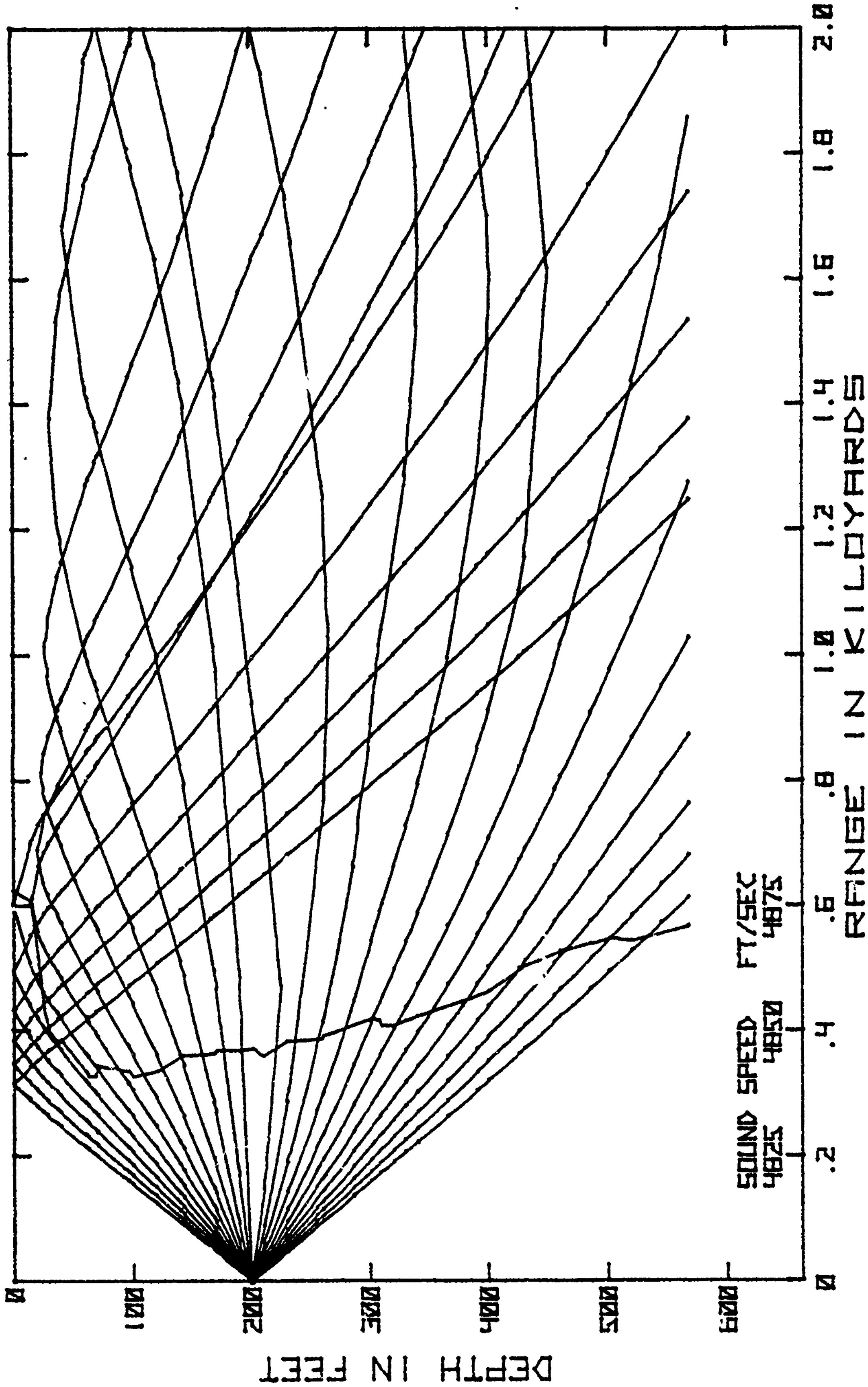

FIG. C-30. RAY DIAGRAM FOR APRIL SOURCE DEPTH 200 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

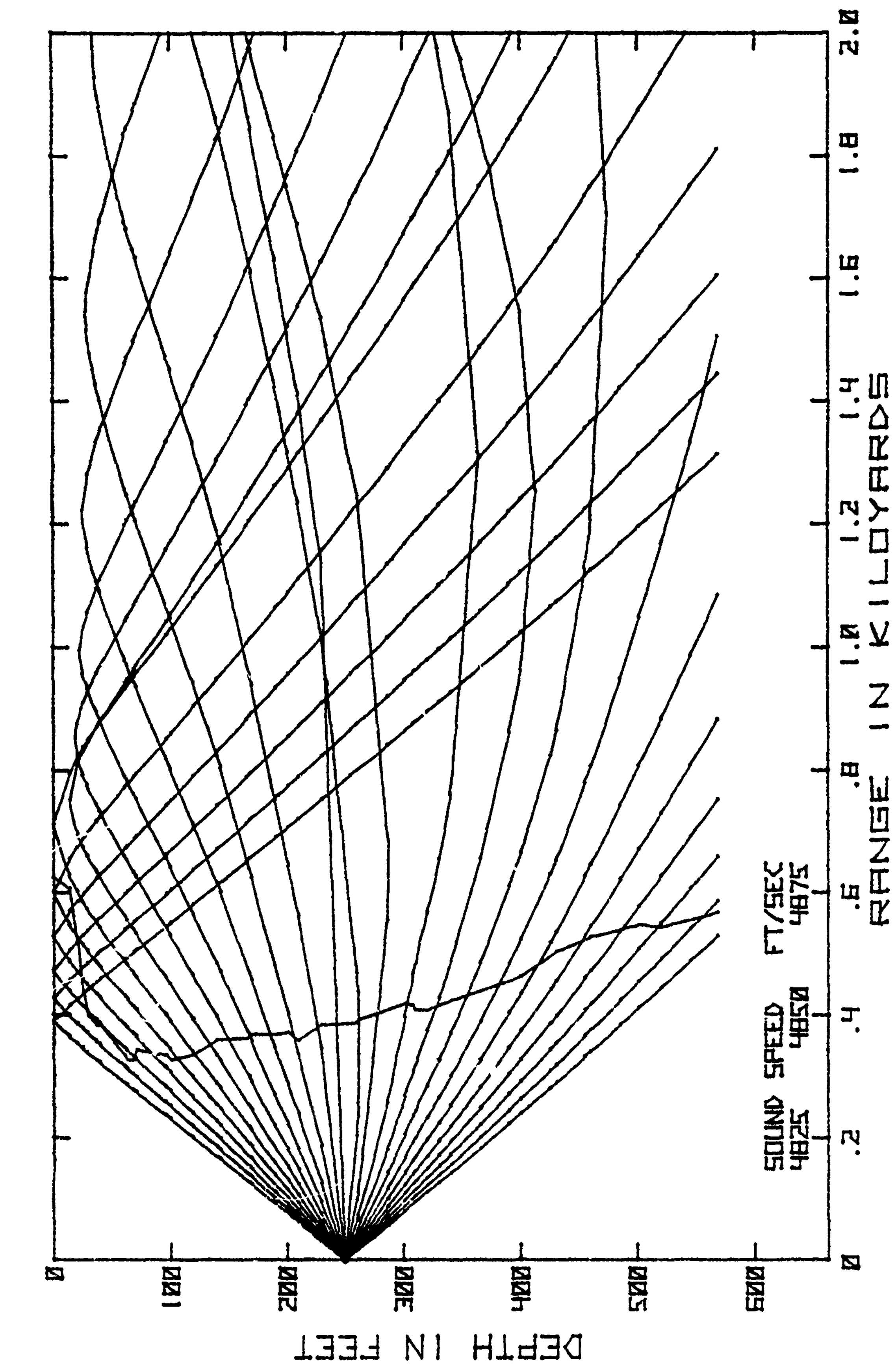

FIG. C-31. RAY DIAGRAM FOR APRIL SOURCE DEPTH 250 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

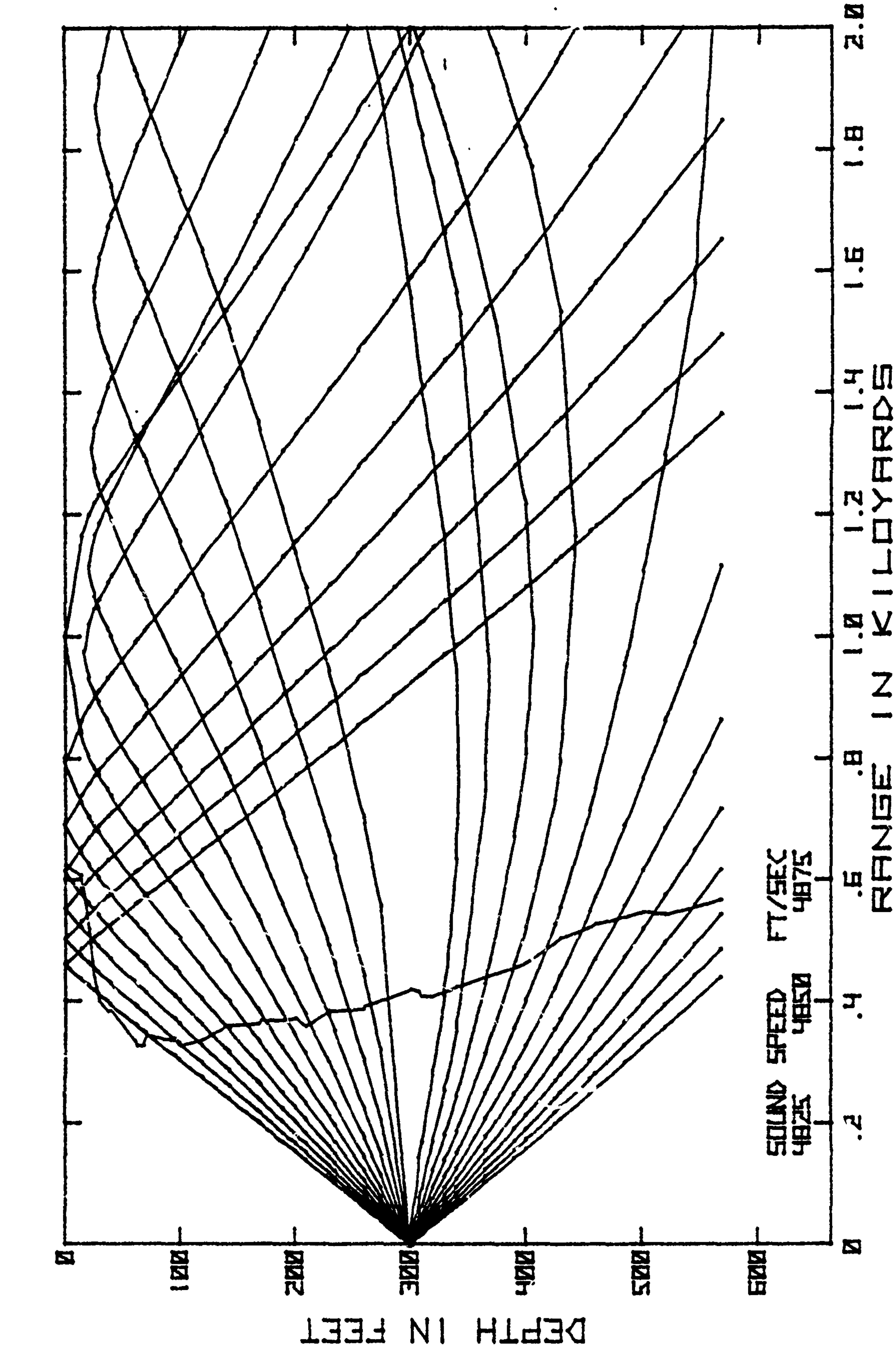

FIG. C-32. RAY DIAGRAM FOR APRIL SOURCE DEPTH 300 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

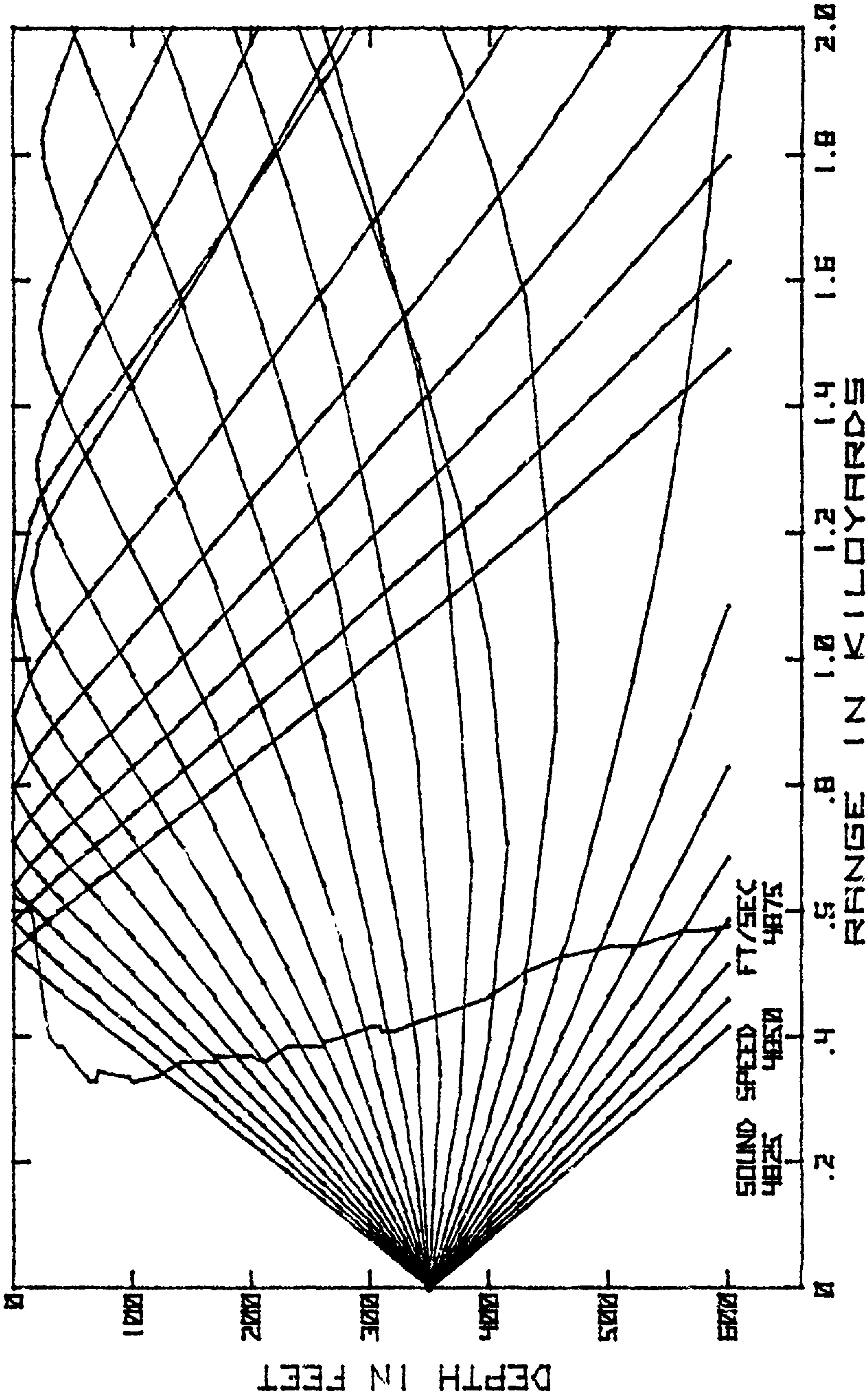

FIG. C-33. RAY DIAGRAM FOR APRIL SOURCE DEPTH 350 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

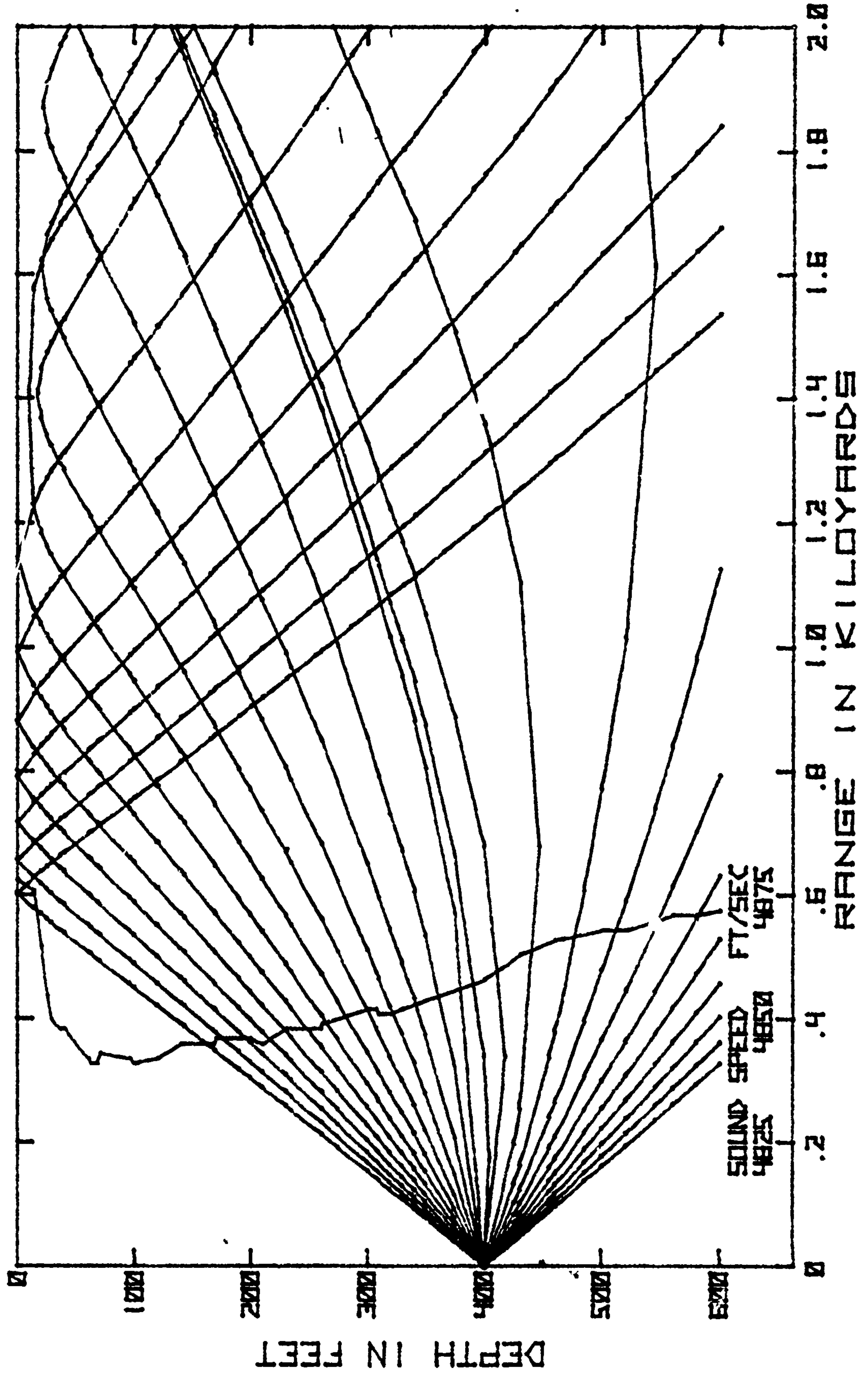

FIG. C-34. RAY DIAGRAM FOR APRIL SOURCE DEPTH 400 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

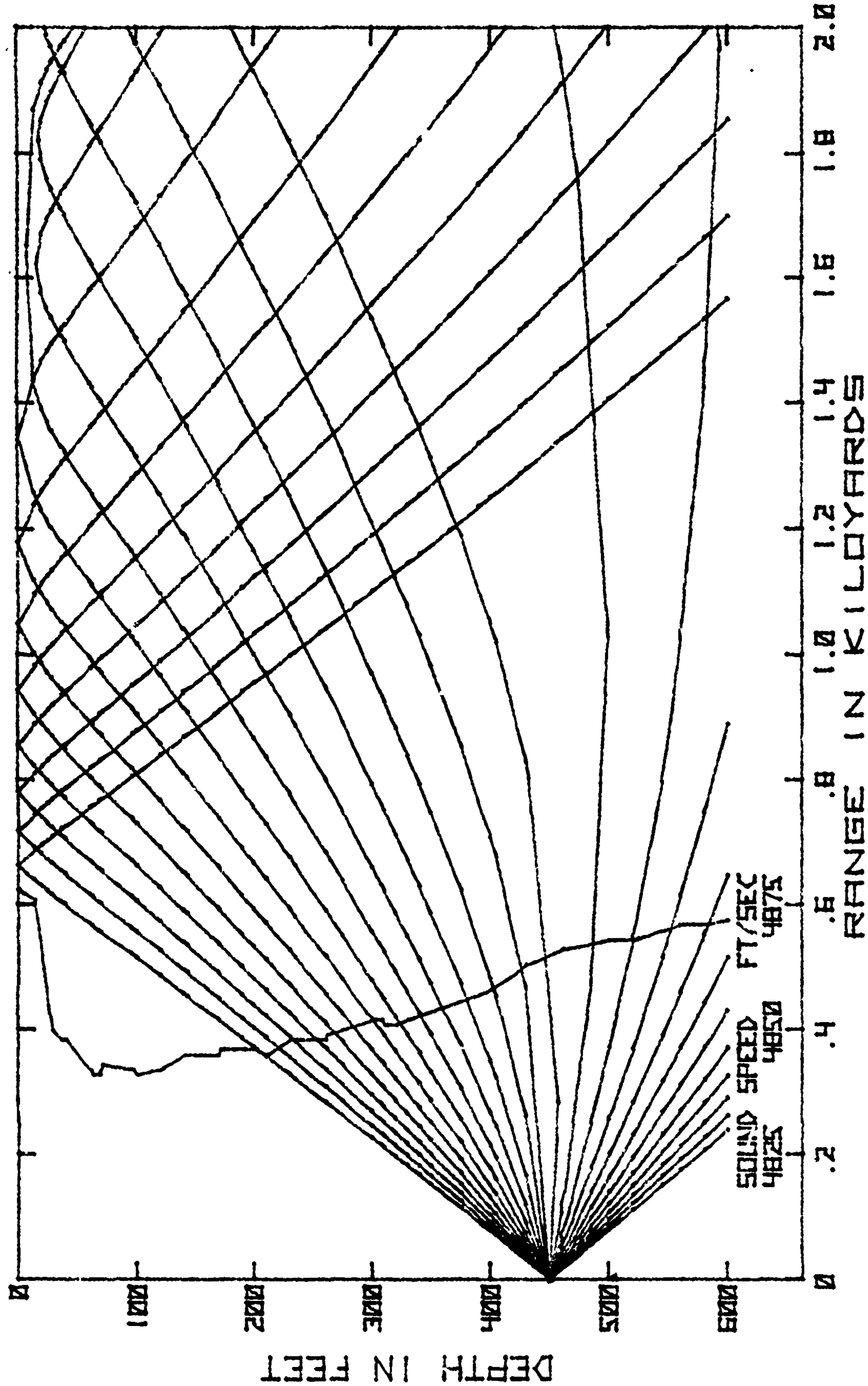

FIG. C-35. RAY DIAGRAM FOR APRIL SOURCE DEPTH 450 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

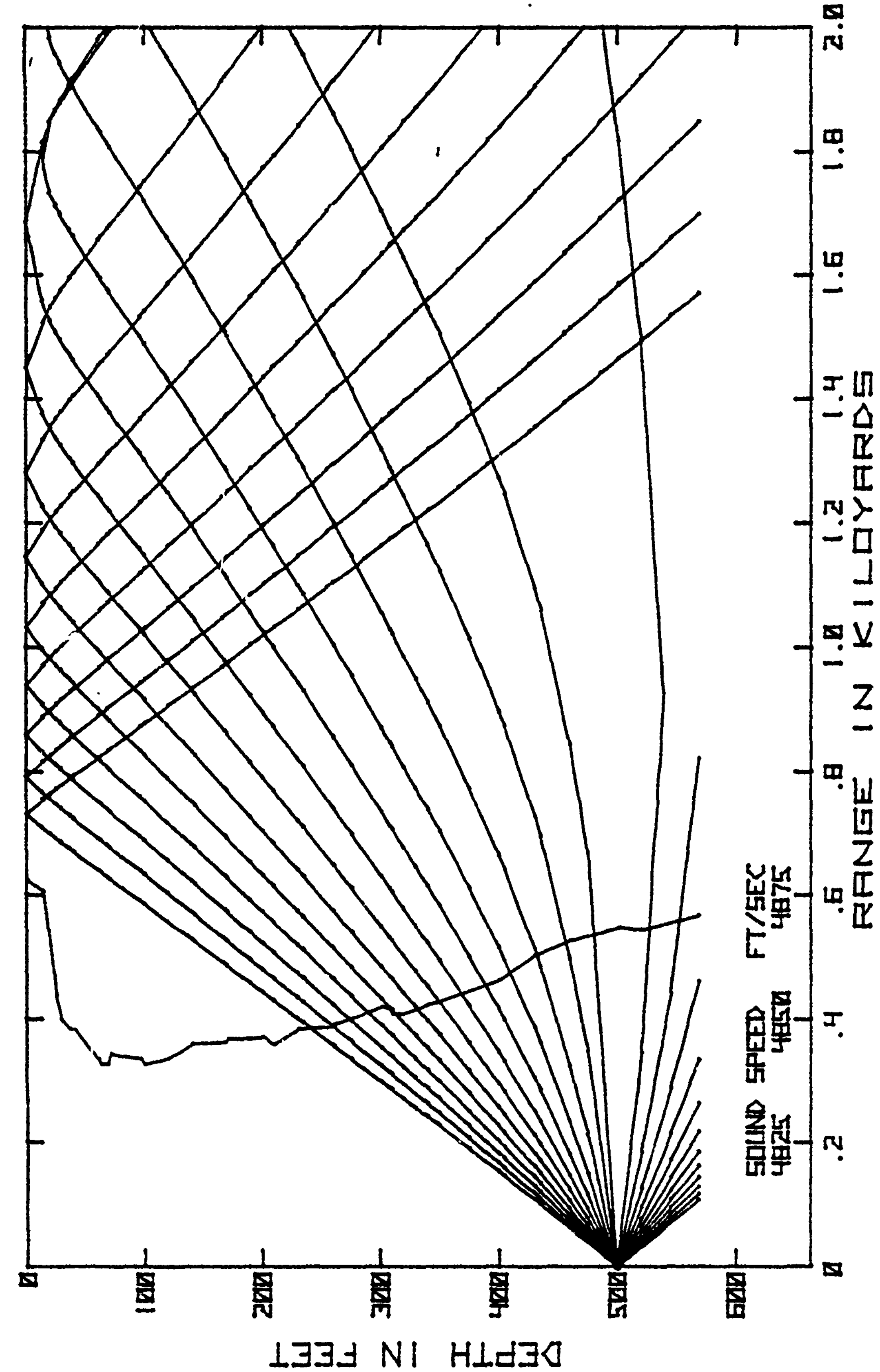

FIG. C-36. RAY DIAGRAM FOR APRIL SOURCE DEPTH 500 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

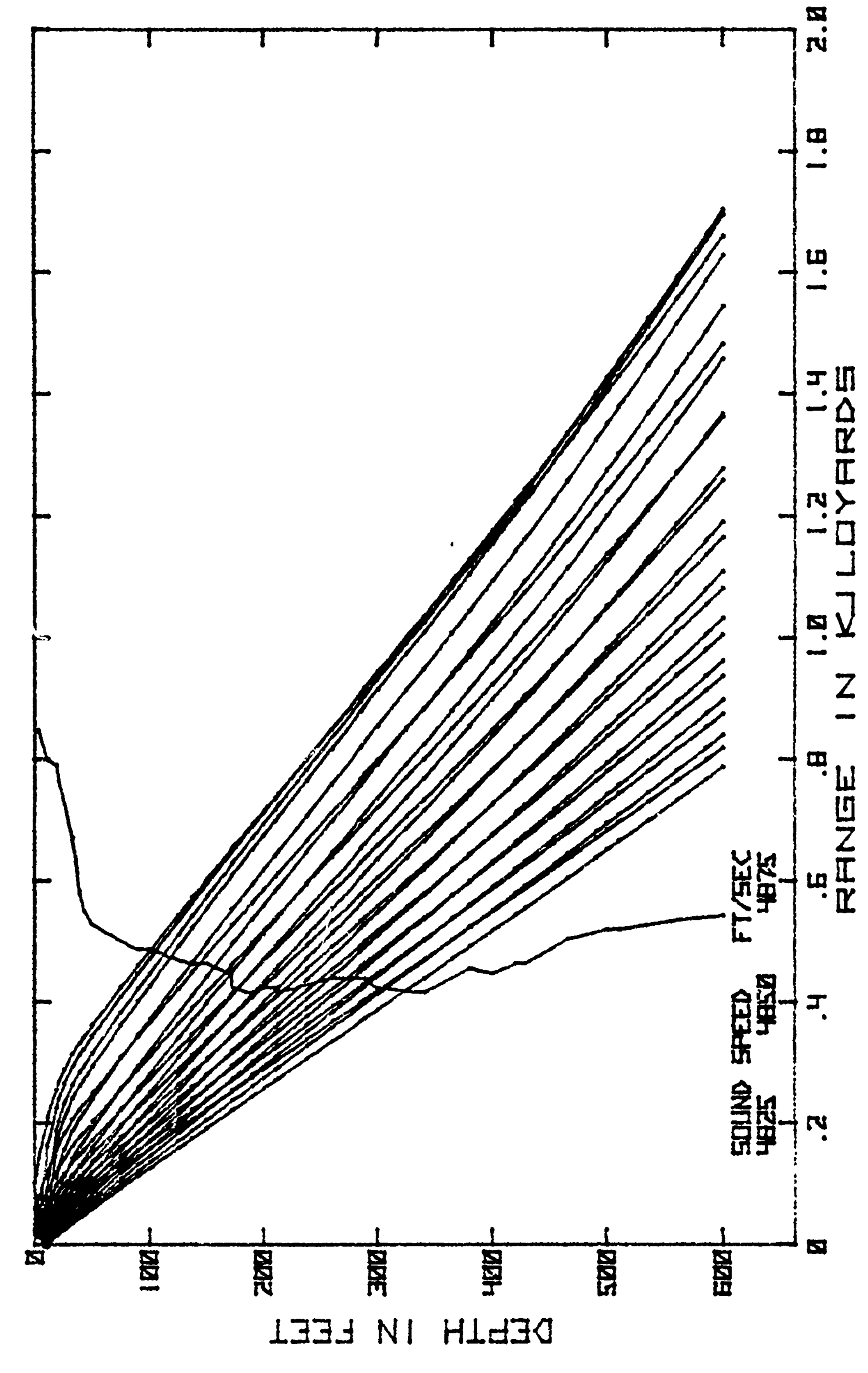

FIG. C-37. RAY DIAGRAM FOR JULY SOURCE DEPTH 10 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

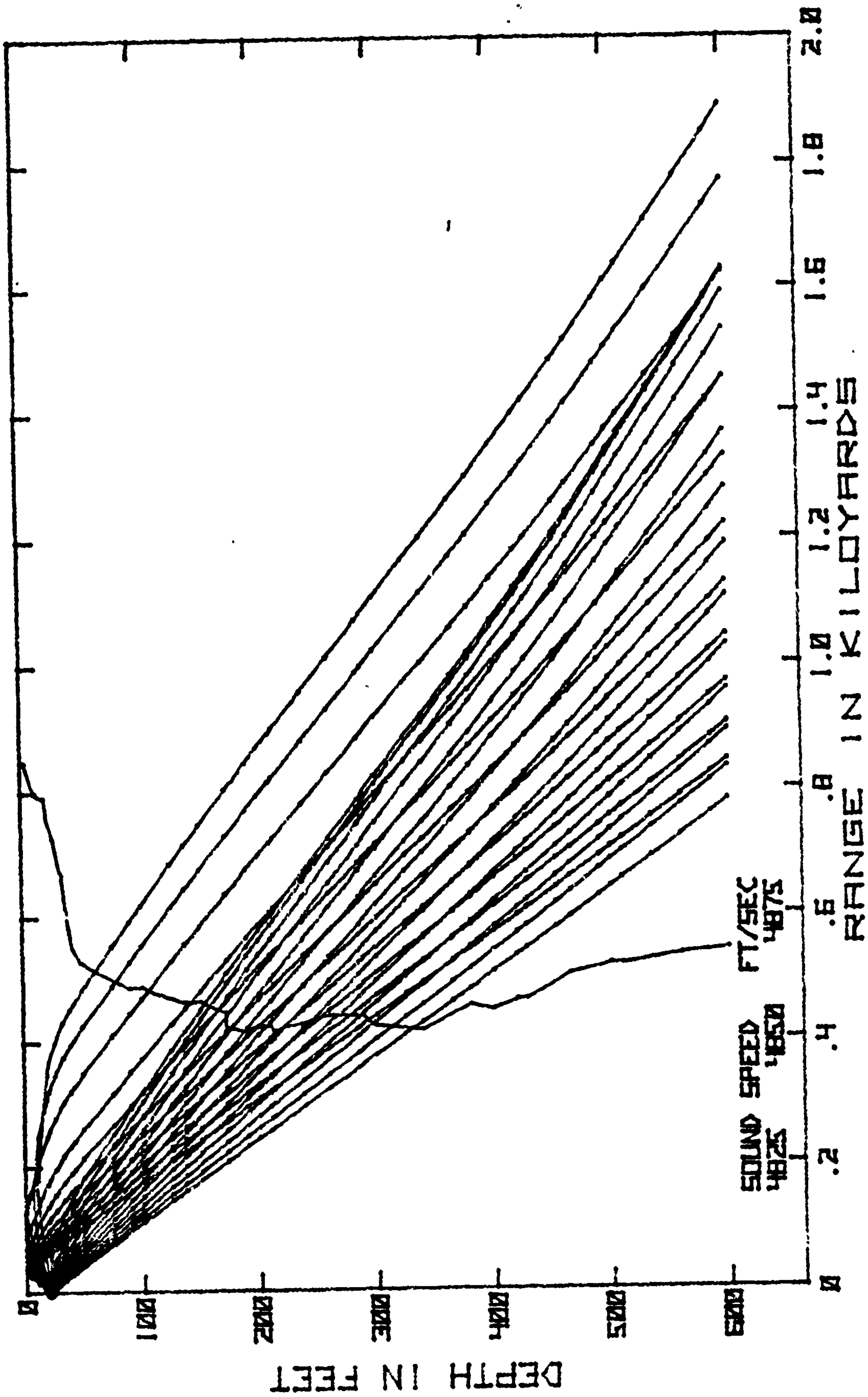

FIG. C-38. RAY DIAGRAM FOR JULY SOURCE DEPTH/20 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

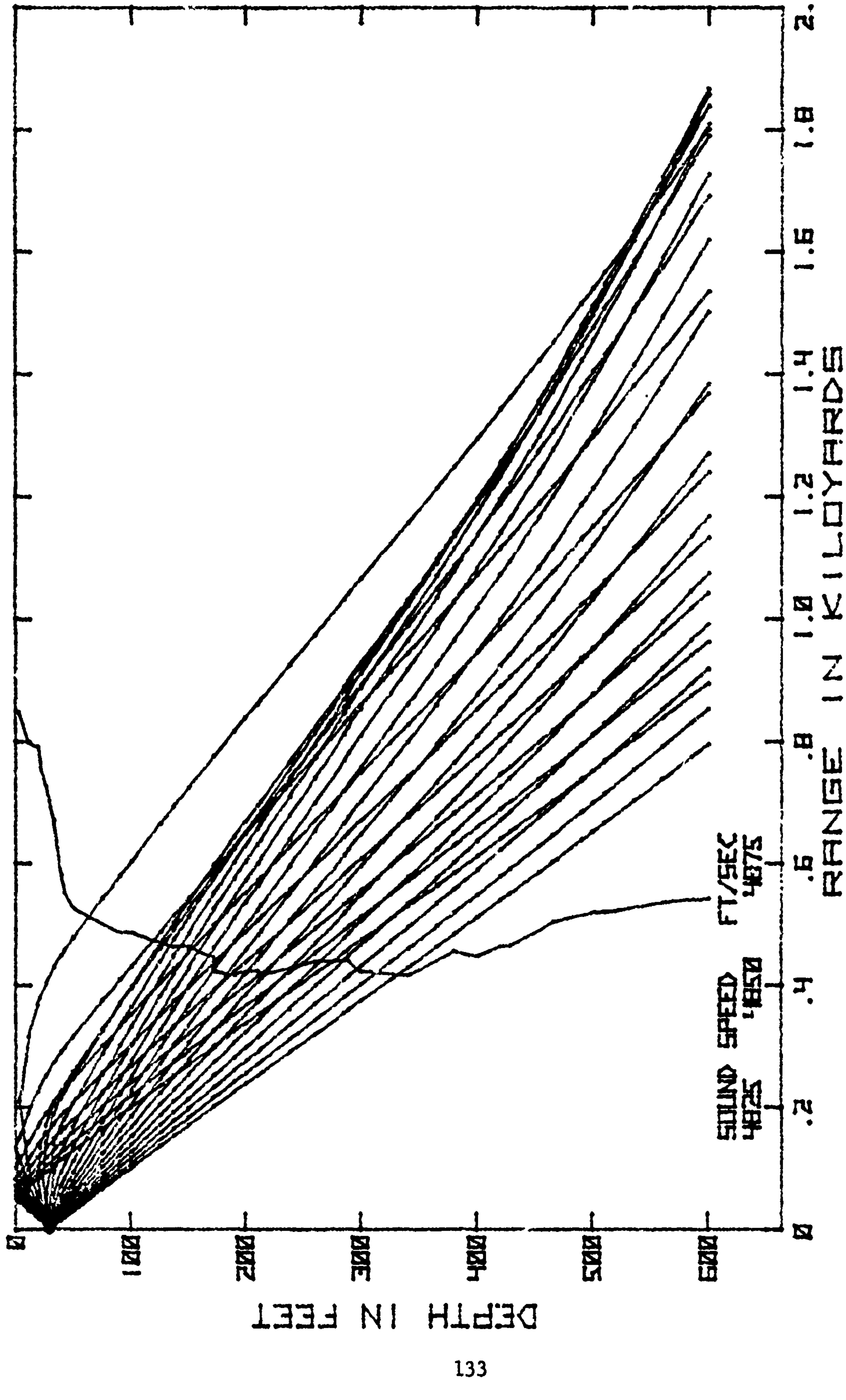

FIG. C-39. RAY DIAGRAM FOR JULY SOURCE DEPTH 30 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

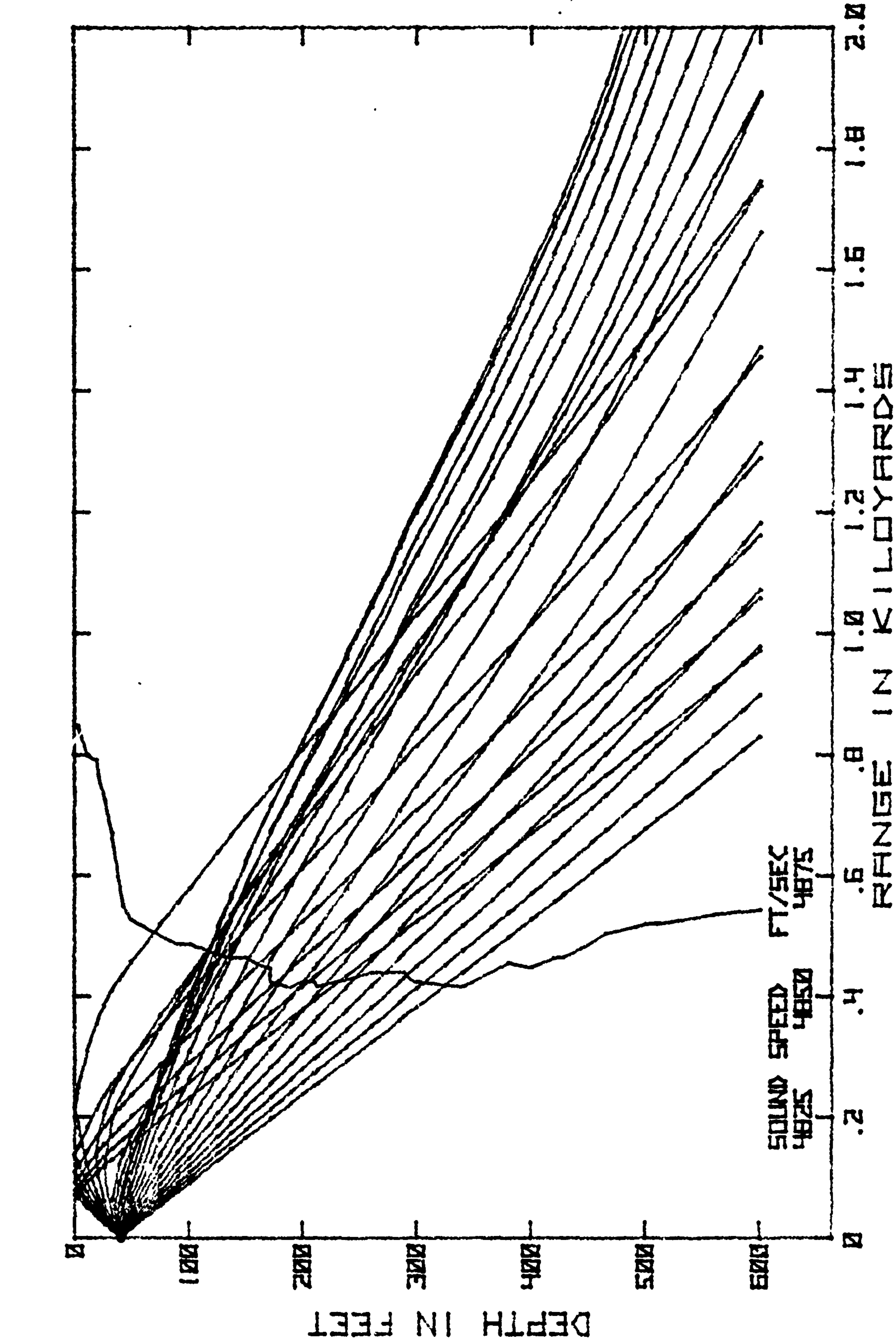

FIG. C-40. RAY DIAGRAM FOR JULY SOURCE DEPTH 40 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

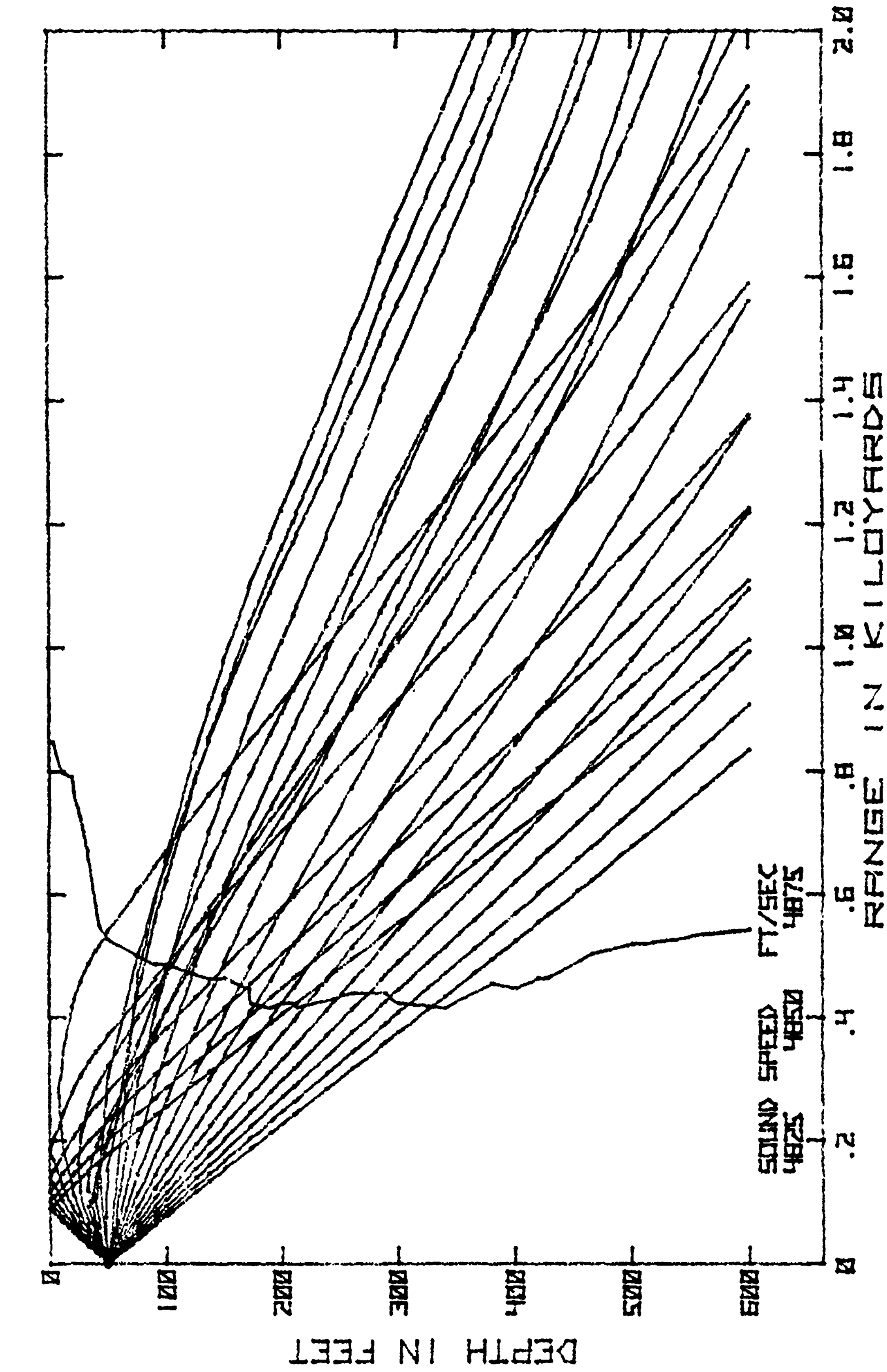

FIG. C-41. RAY DIAGRAM FOR JULY SOURCE DEPTH 50 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

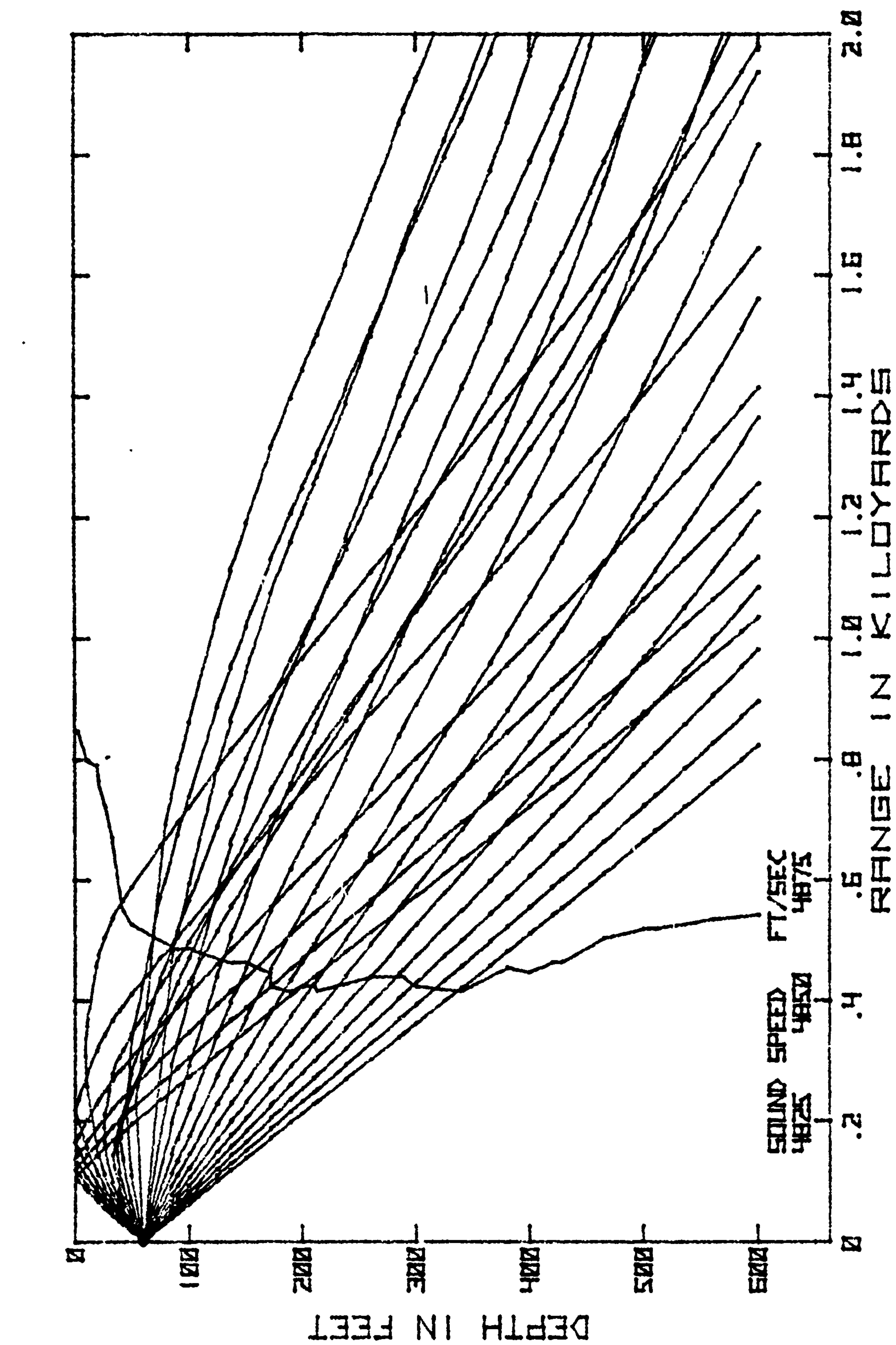

FIG. C-42. RAY DIAGRAM FOR JULY SOURCE DEPTH 60 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

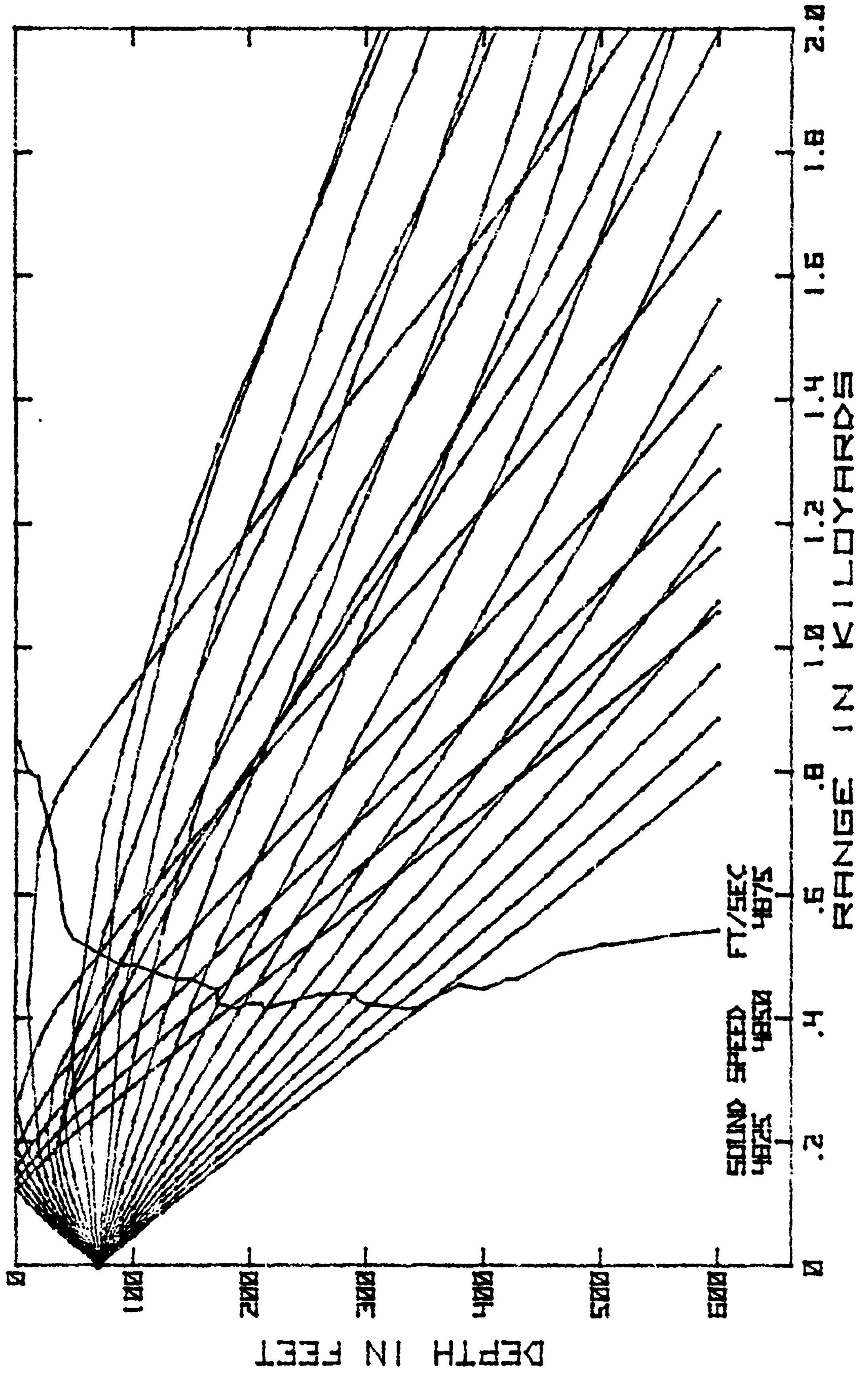

FIG. C-43. RAY DIAGRAM FOR JULY SOURCE DEPTH 70 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

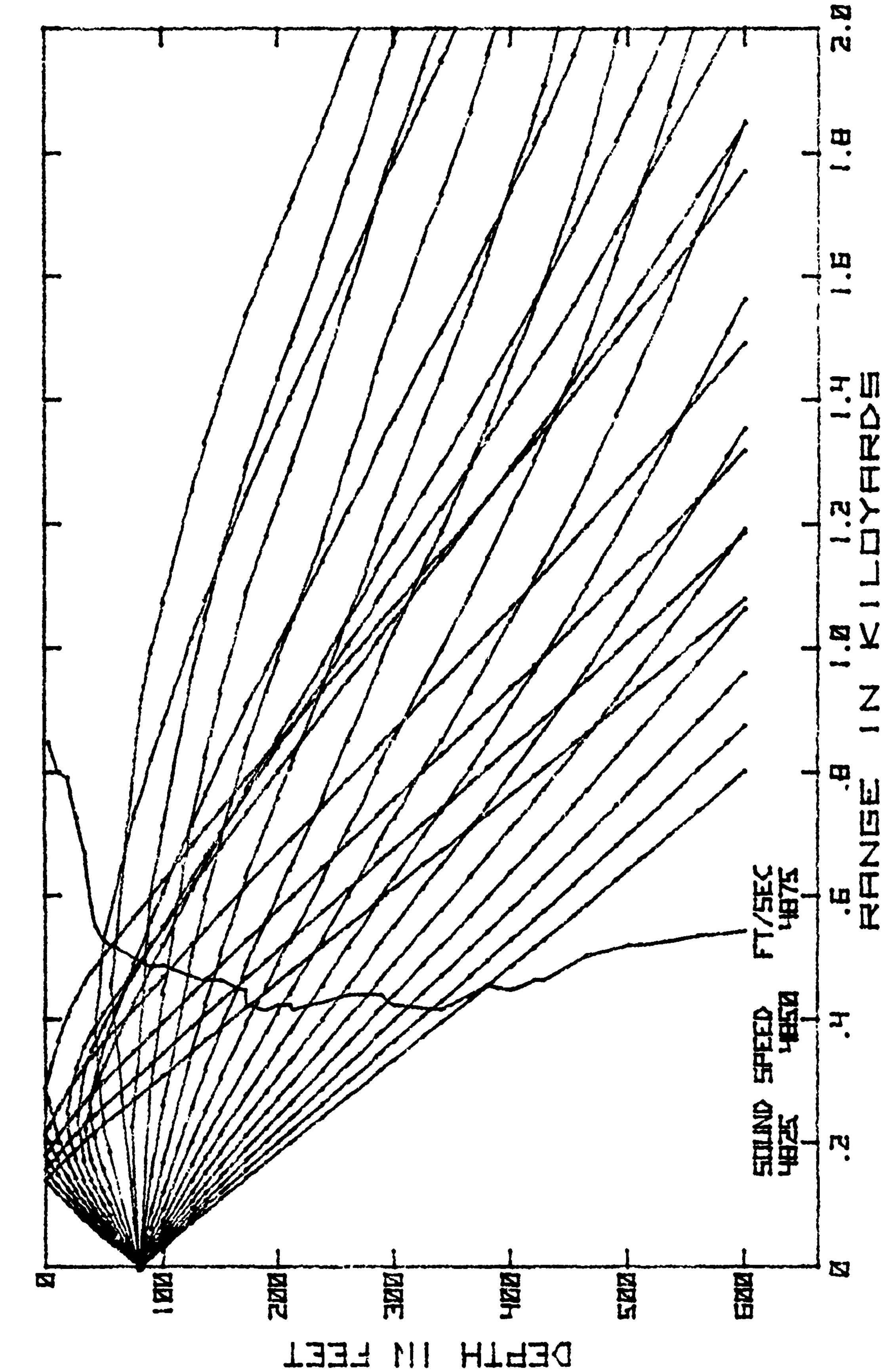

FIG. C-44. RAY DIAGRAM FOR JULY SOURCE DEPTH 80 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

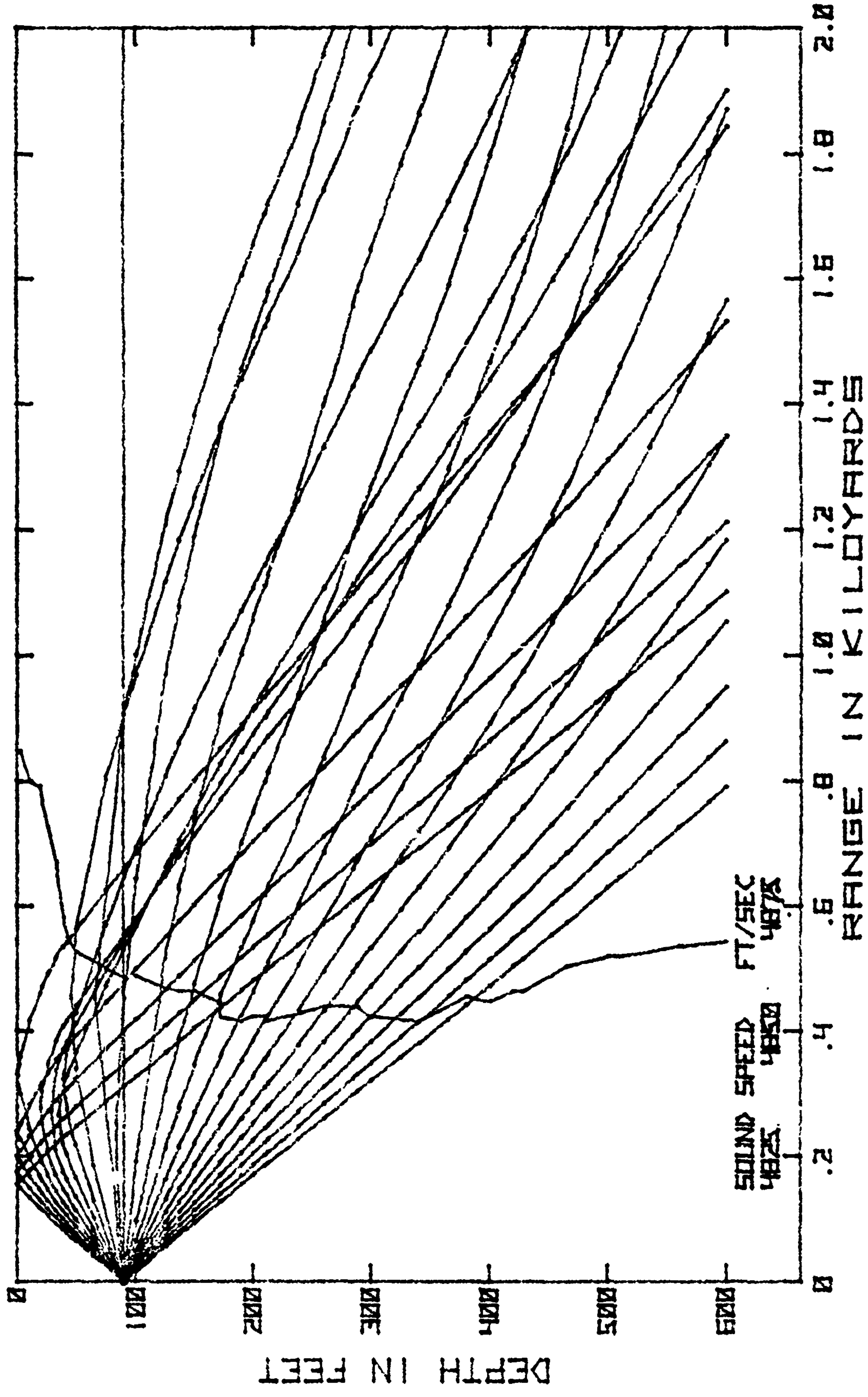

FIG. C-45. RAY DIAGRAM FOR JULY SOURCE DEPTH 90 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

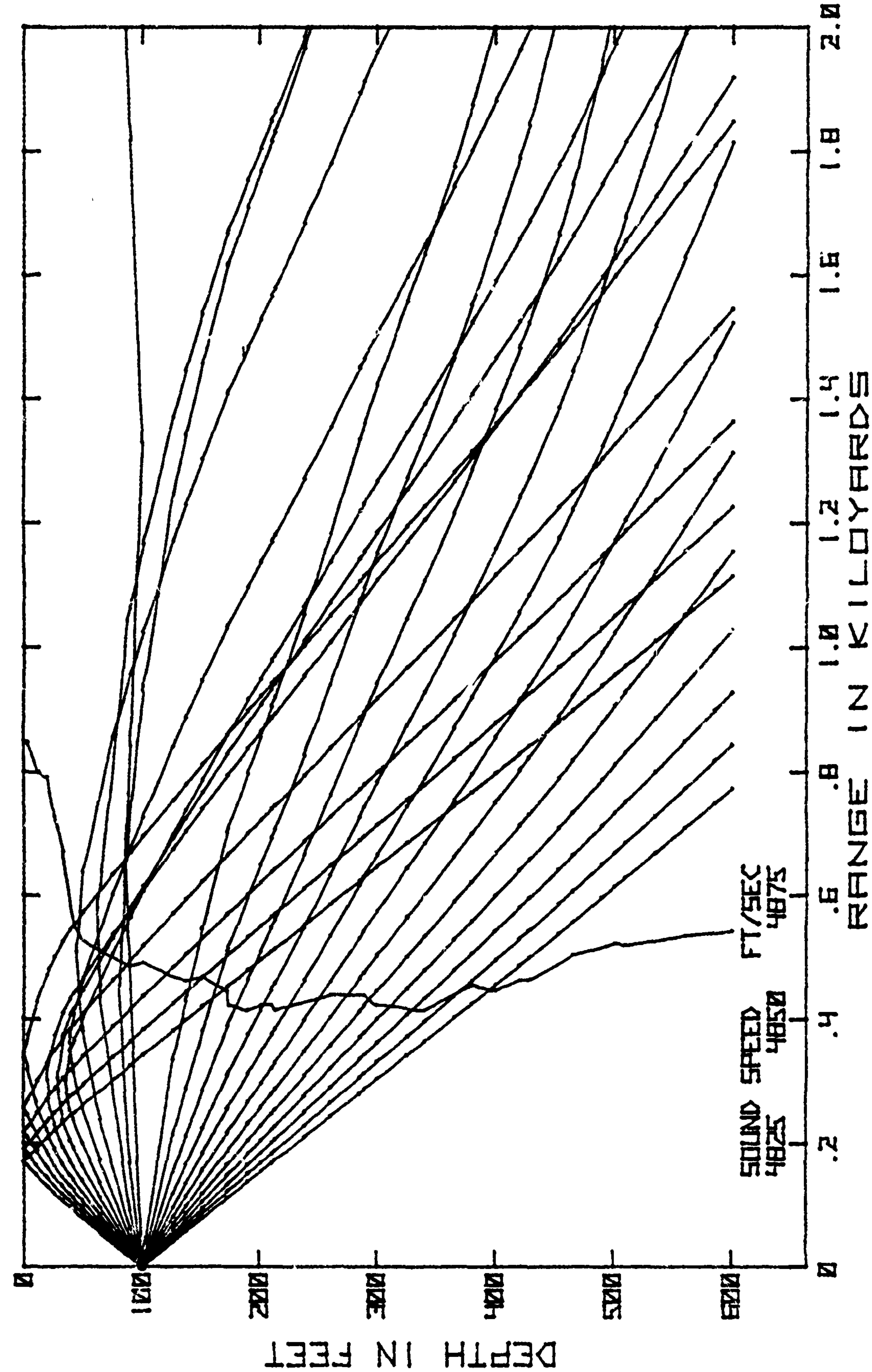

FIG. C-46. RAY DIAGRAM FOR JULY SOURCE DEPTH 100 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

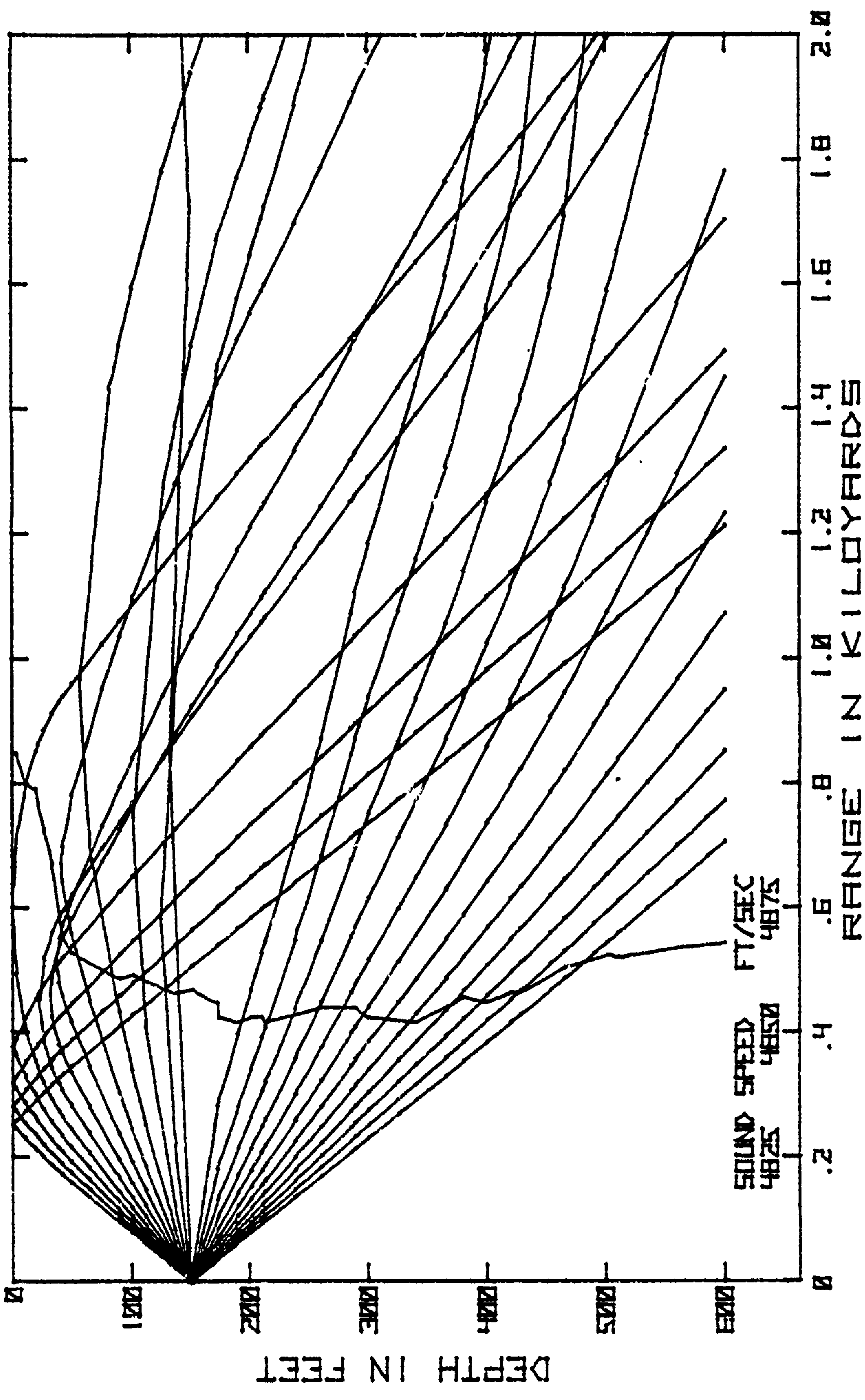

FIG. C-47. RAY DIAGRAM FOR JULY SOURCE DEPTH 150 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

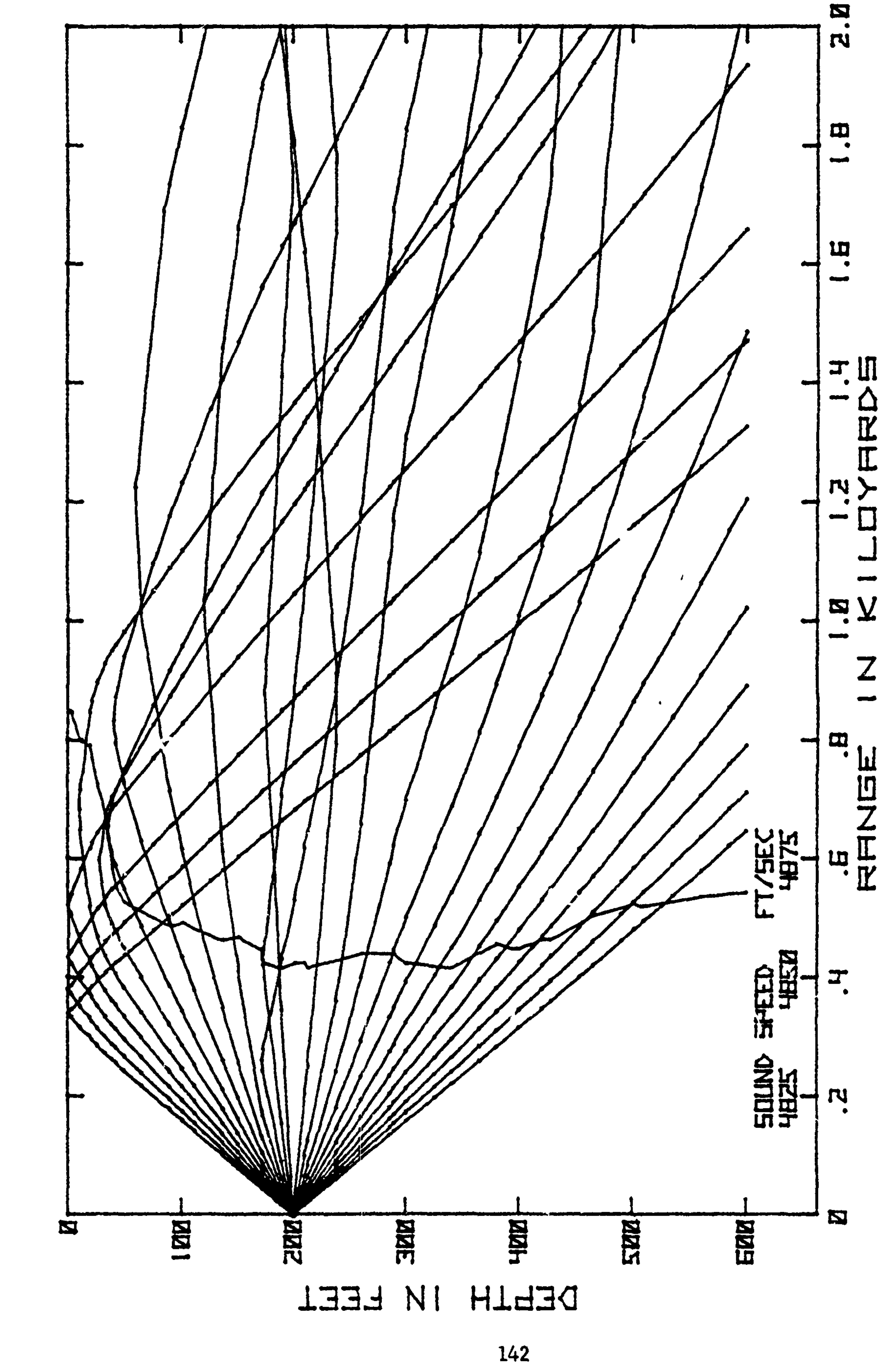

FIG. C-48. RAY DIAGRAM FOR JULY SOURCE DEPTH 200 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

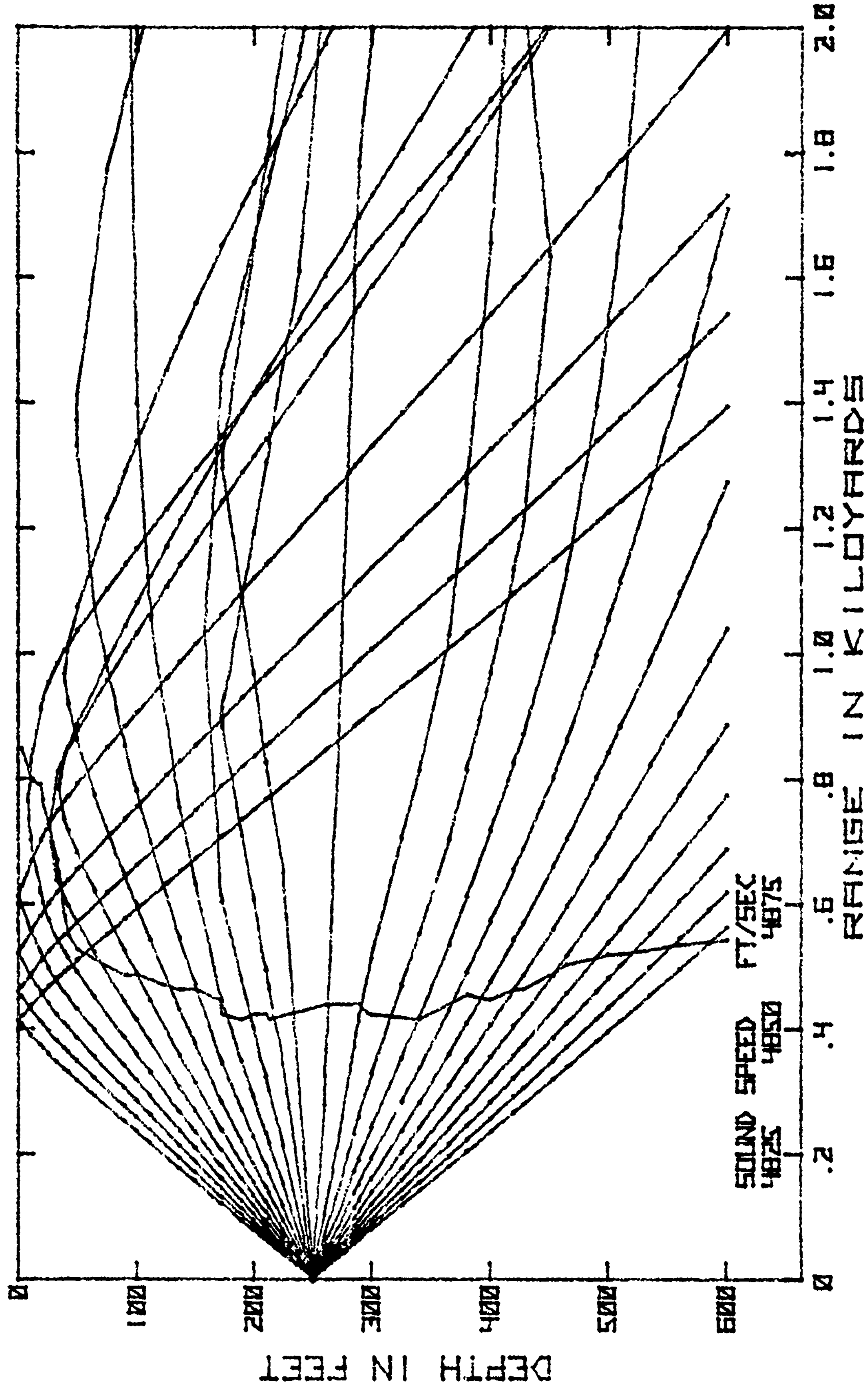

FIG. C-49. RAY DIAGRAM FOR JULY SOURCE DEPTH 250 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

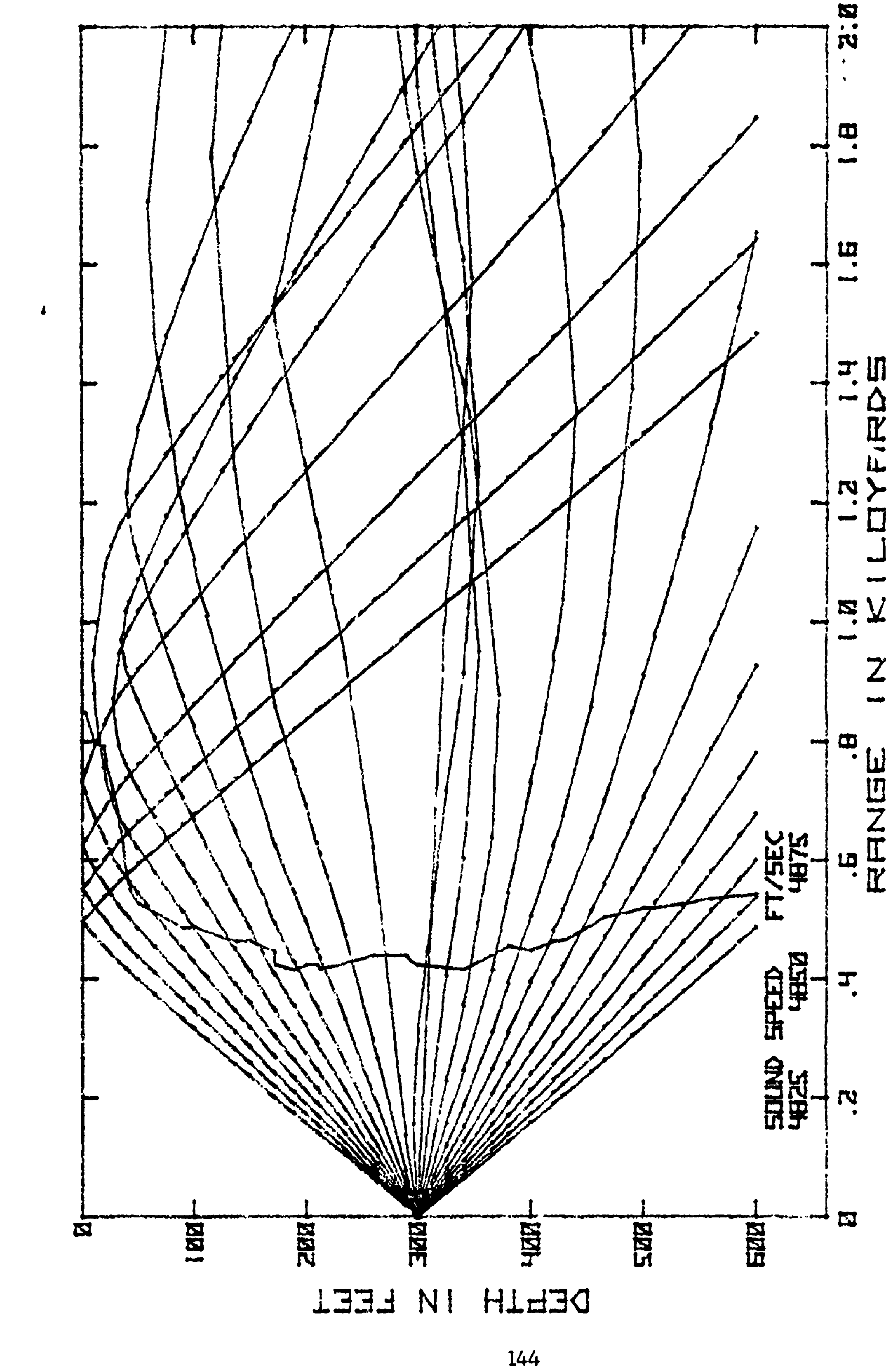

FIG. C-50. RAY DIAGRAM FOR JULY SOURCE DEPTH 300 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

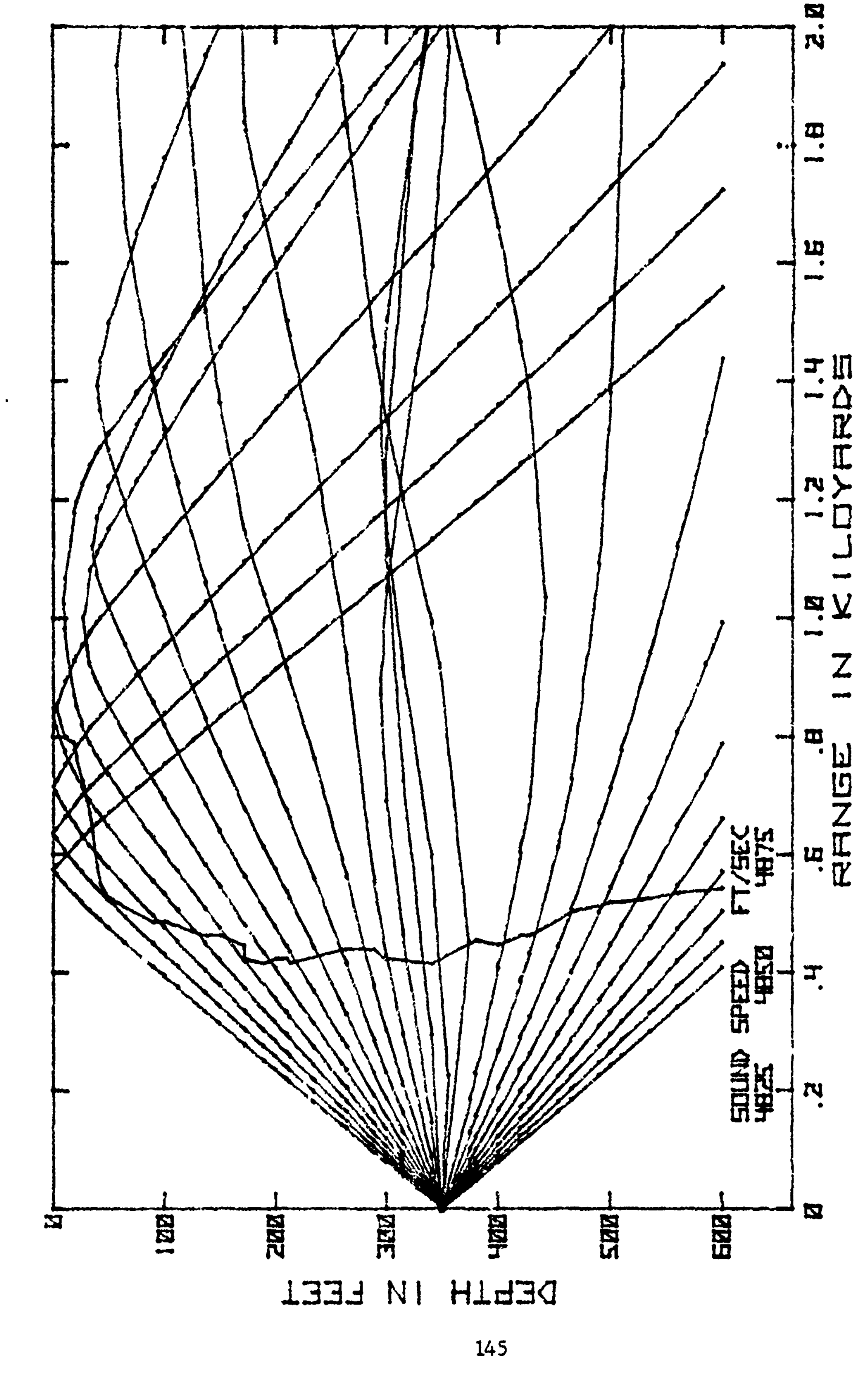

FIG. C-51. RAY DIAGRAM FOR JULY SOURCE DEPTH 350 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

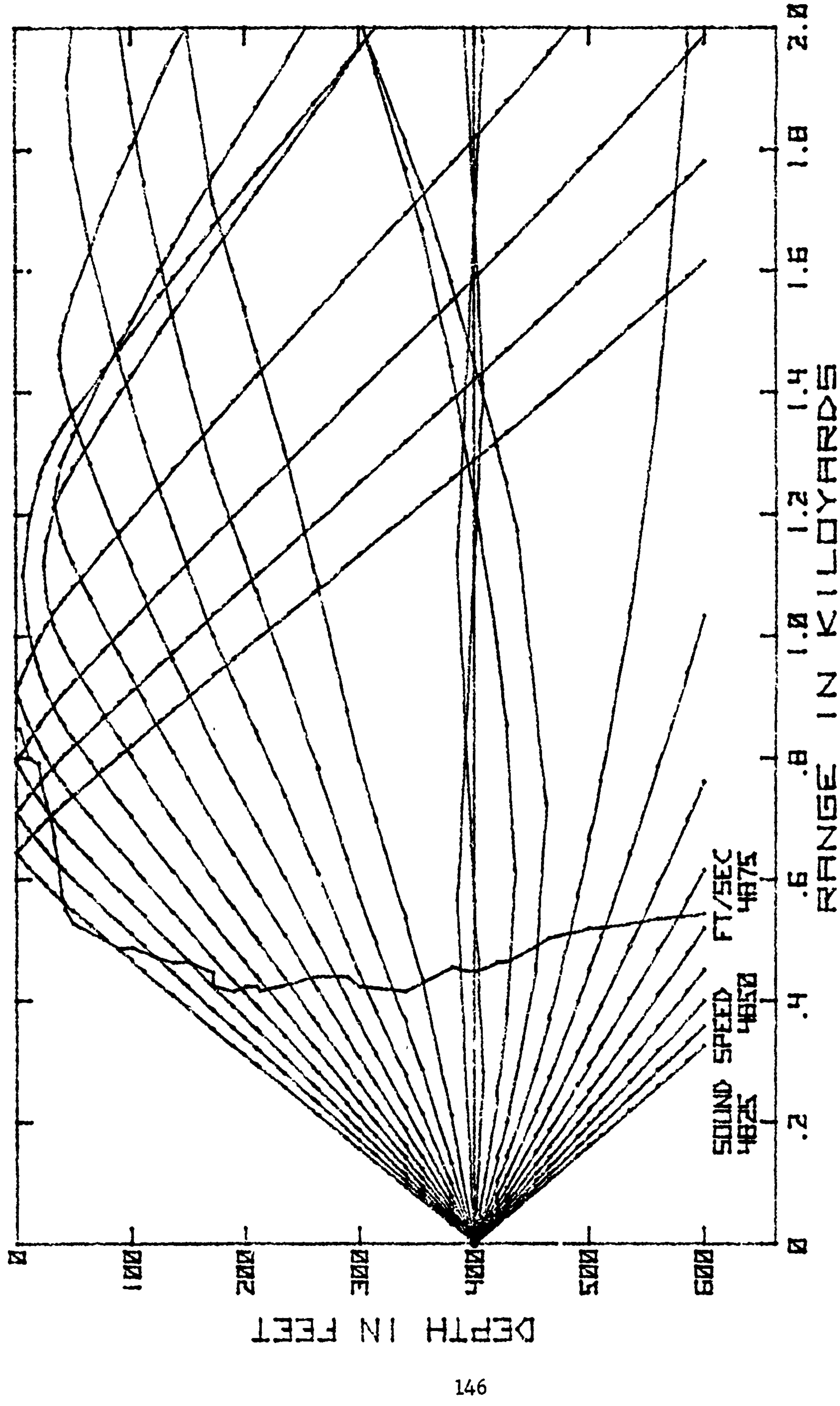

FIG. C-52. RAY DIAGRAM FOR JULY SOURCE DEPTH 400 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

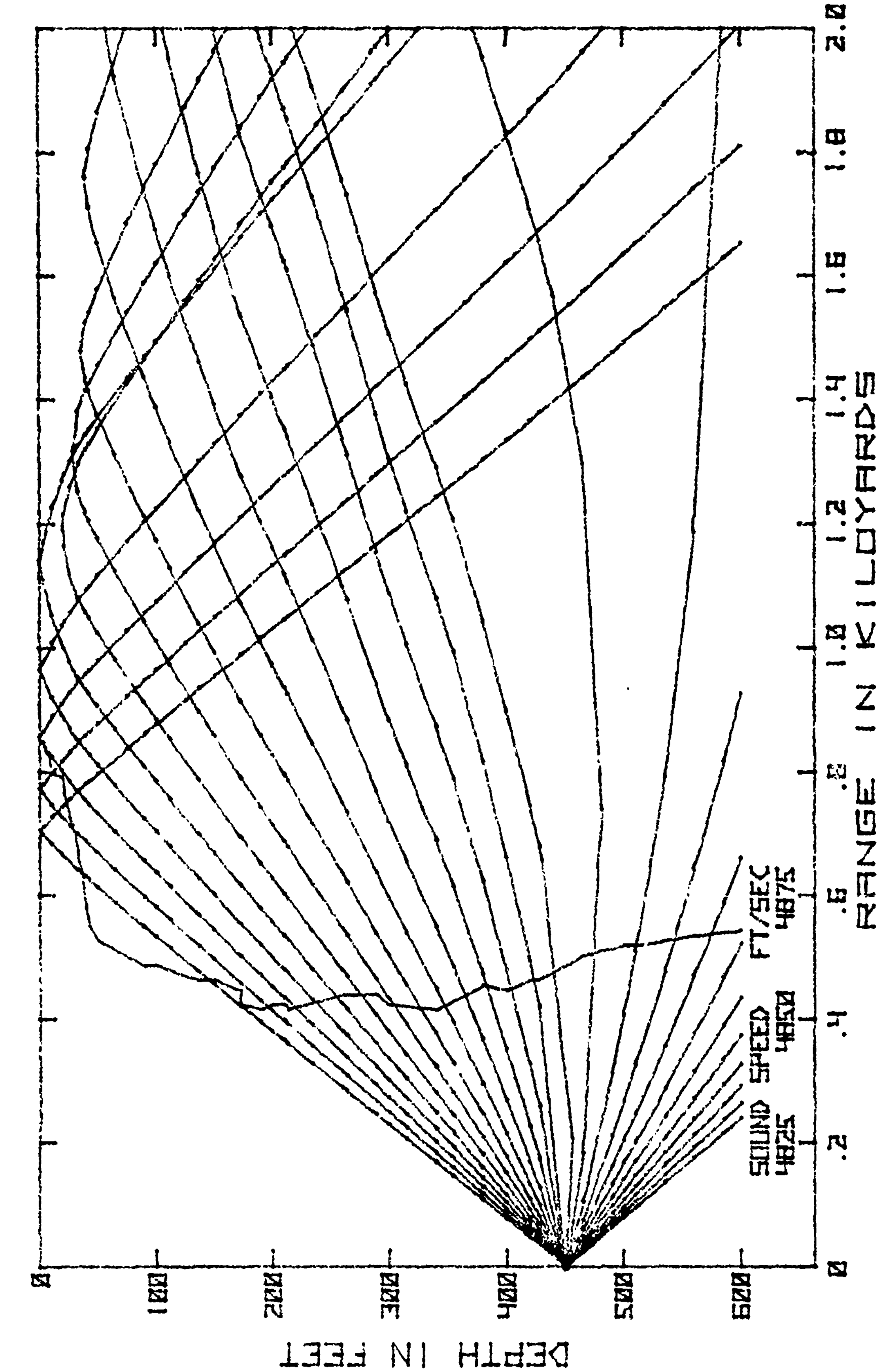

FIG. C-53. RAY DIAGRAM FOR JULY SOURCE DEPTH 450 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

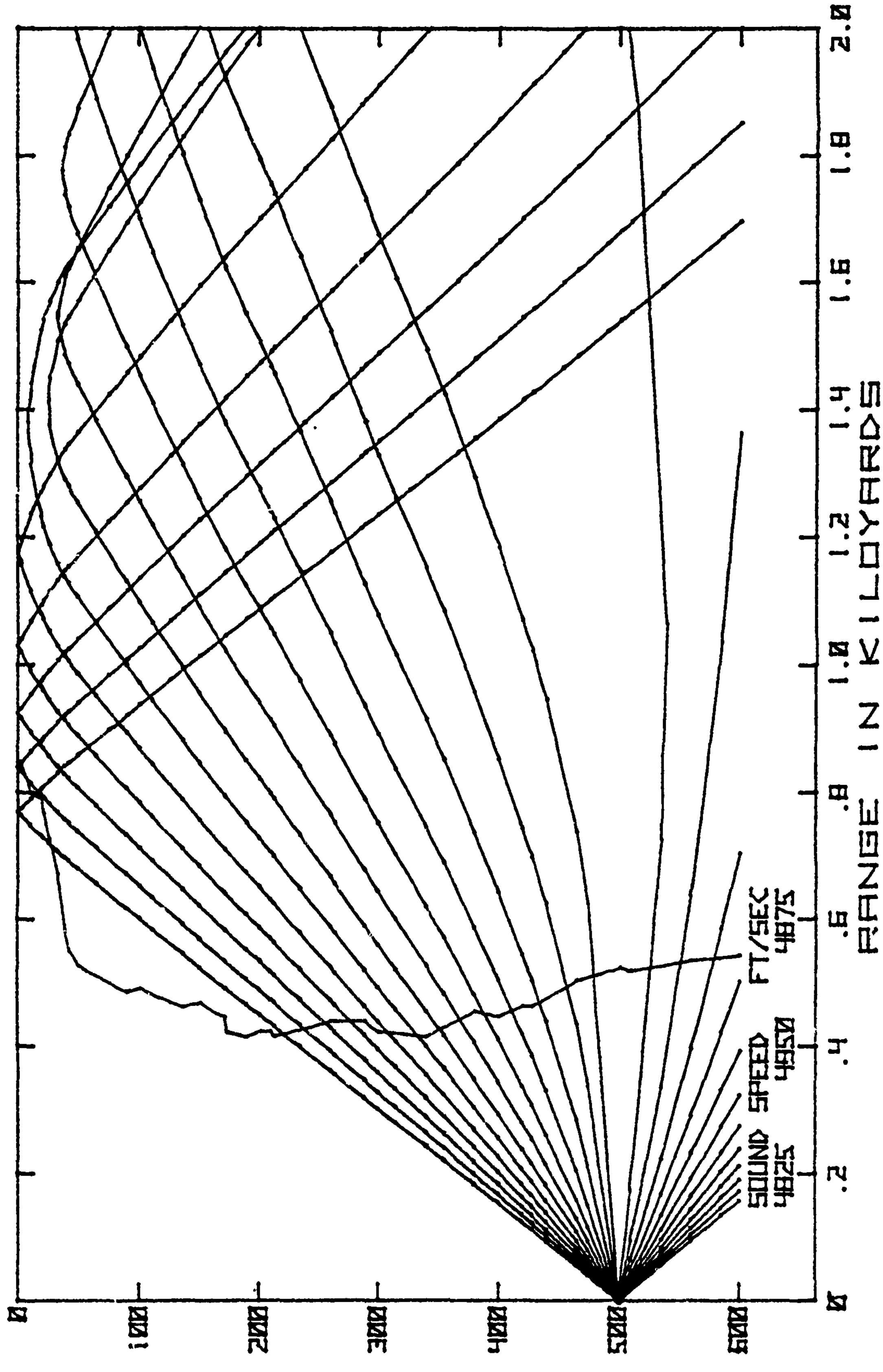

FIG. C-54. RAY DIAGRAM FOR JULY SOURCE DEPTH 500 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

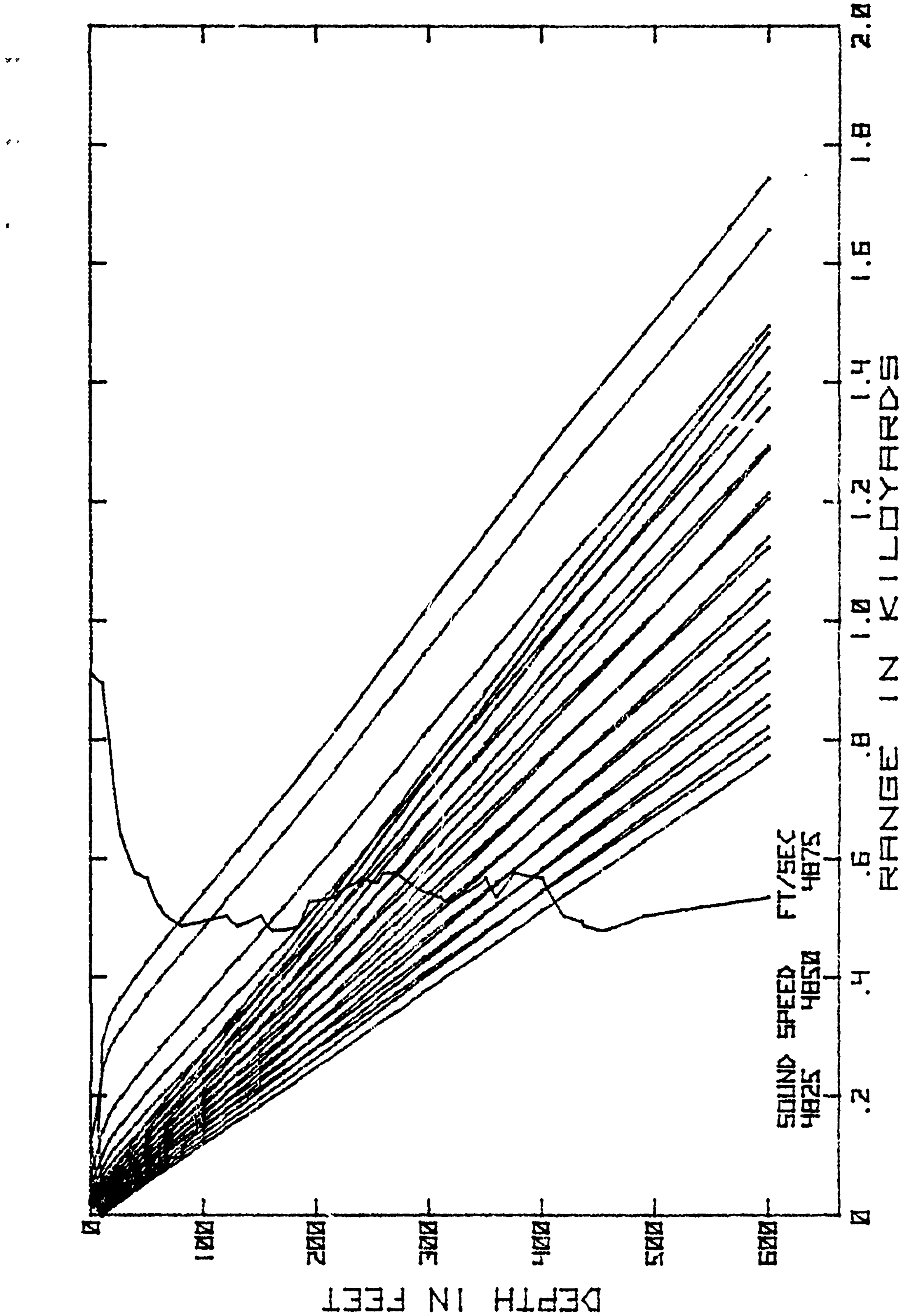

FIG. C-55. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 10 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

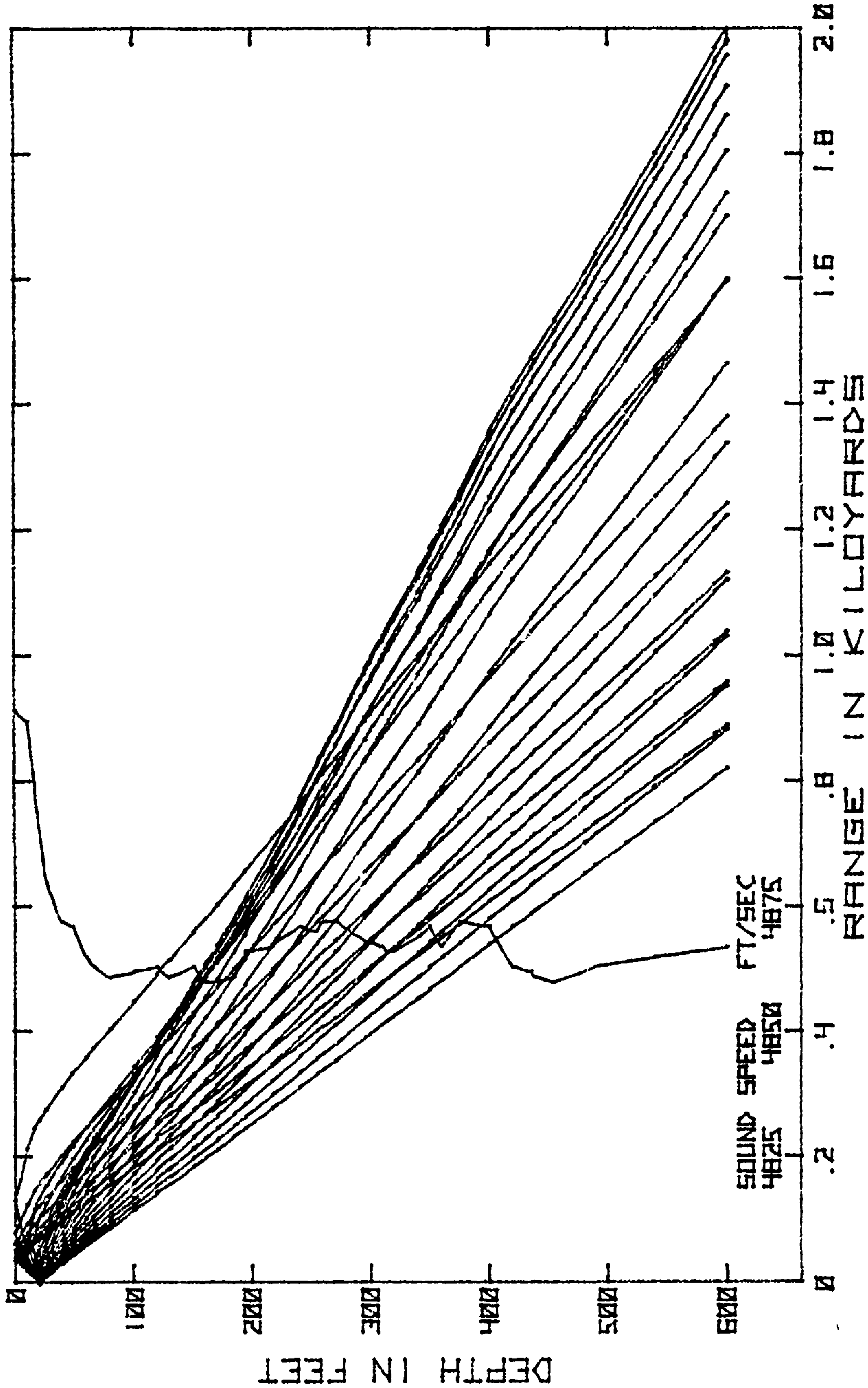

FIG. C-56. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 20 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

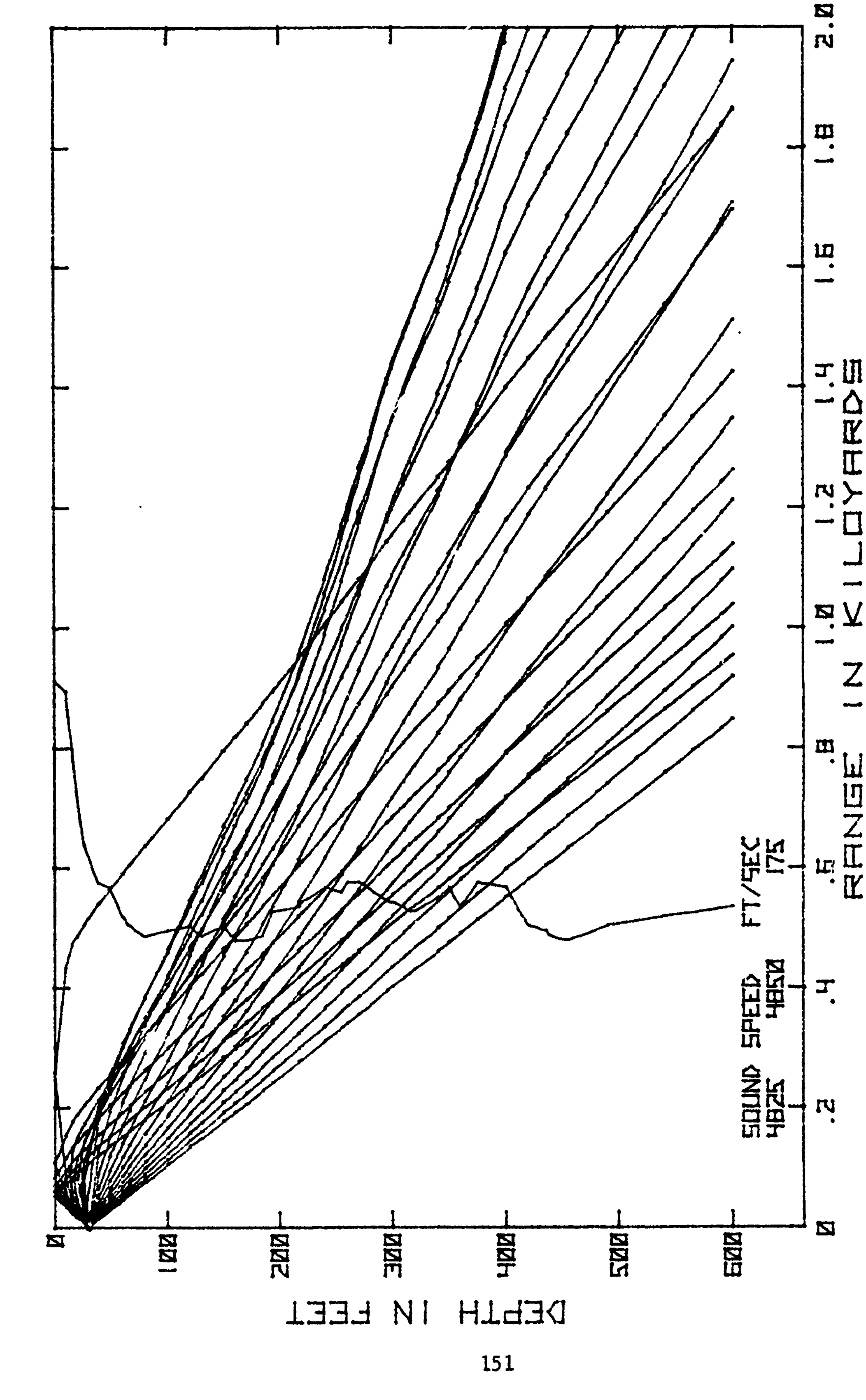

FIG. C-57. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 30 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

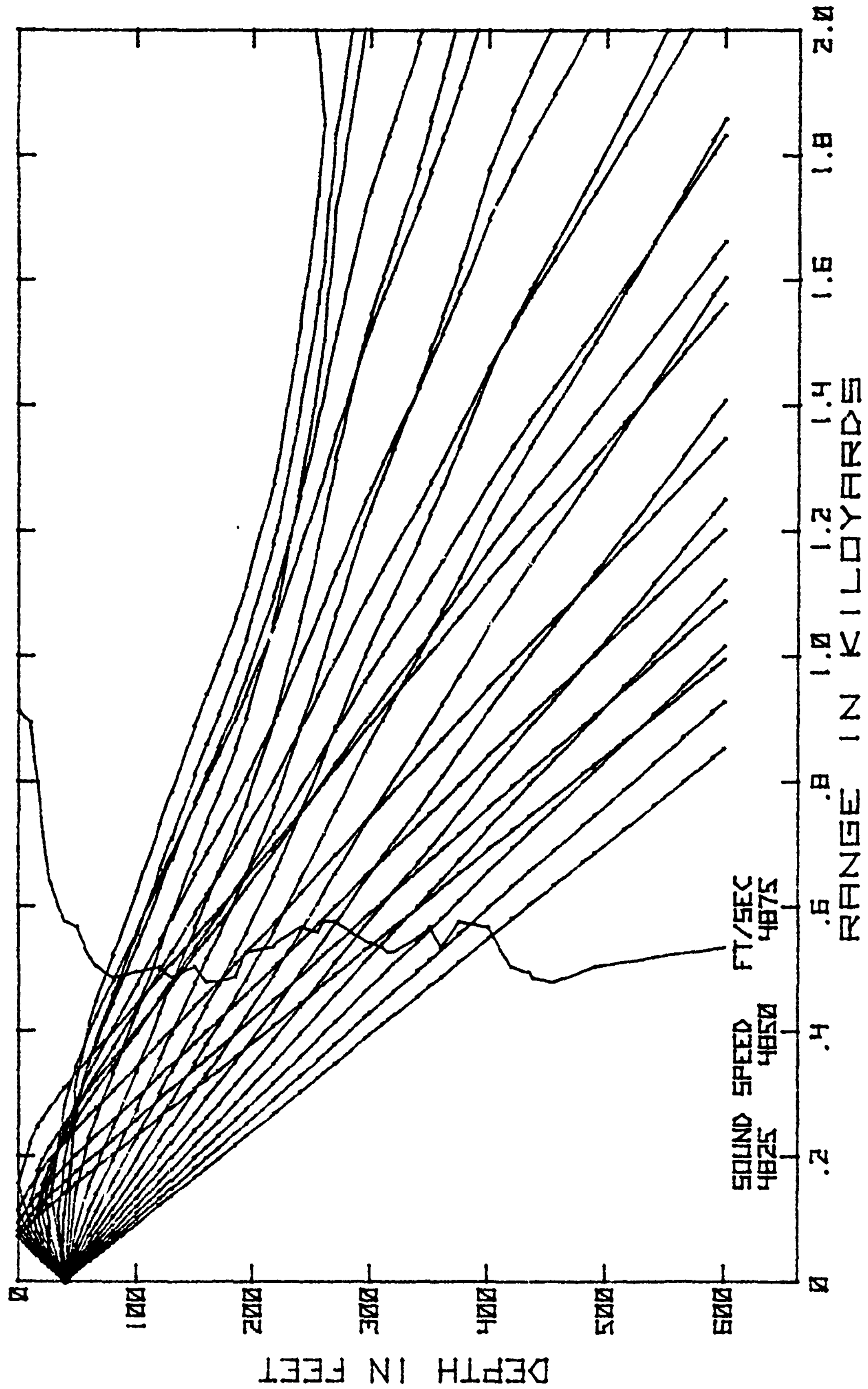

FIG. C-58. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 40 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

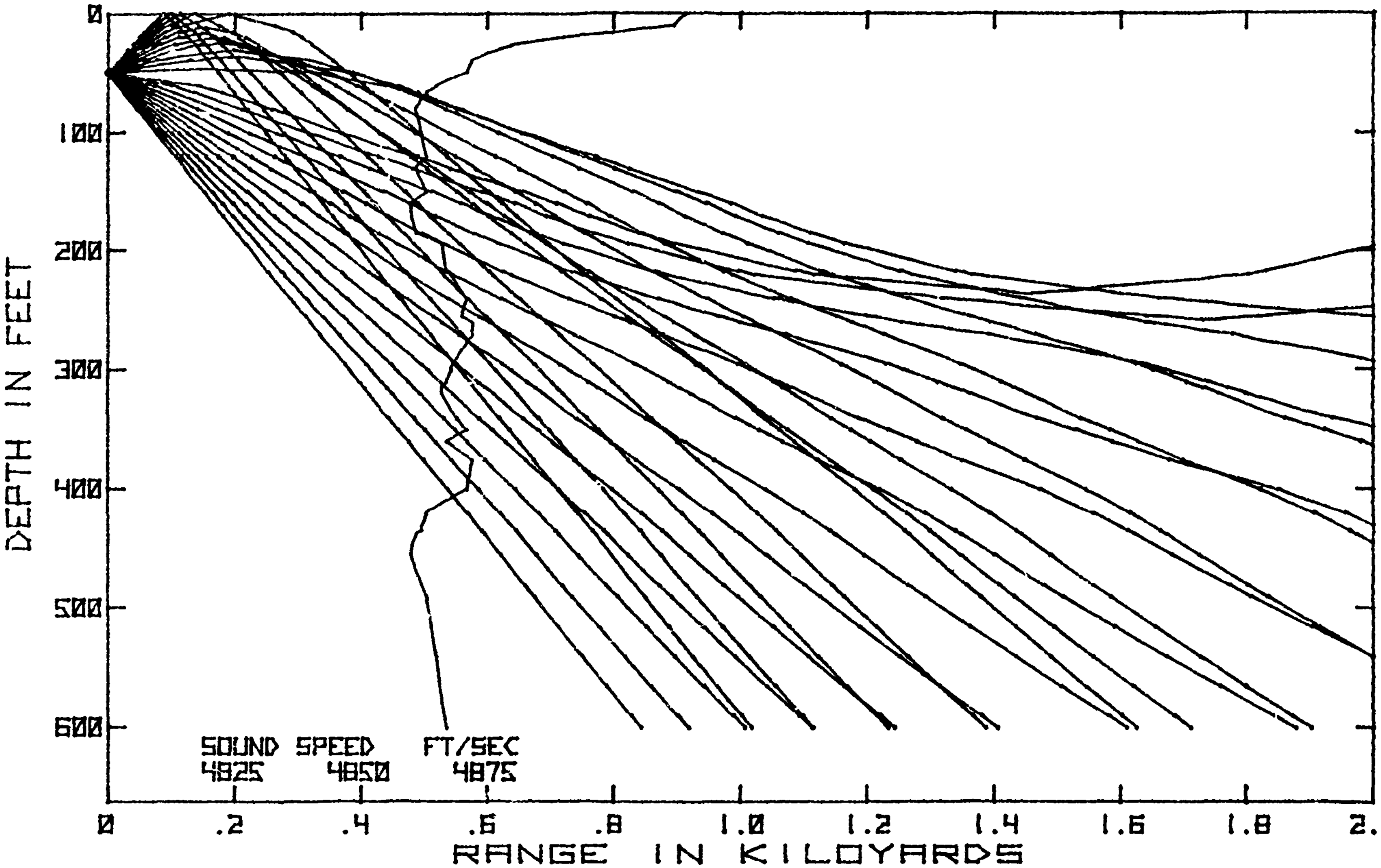

FIG. C-59. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 50 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

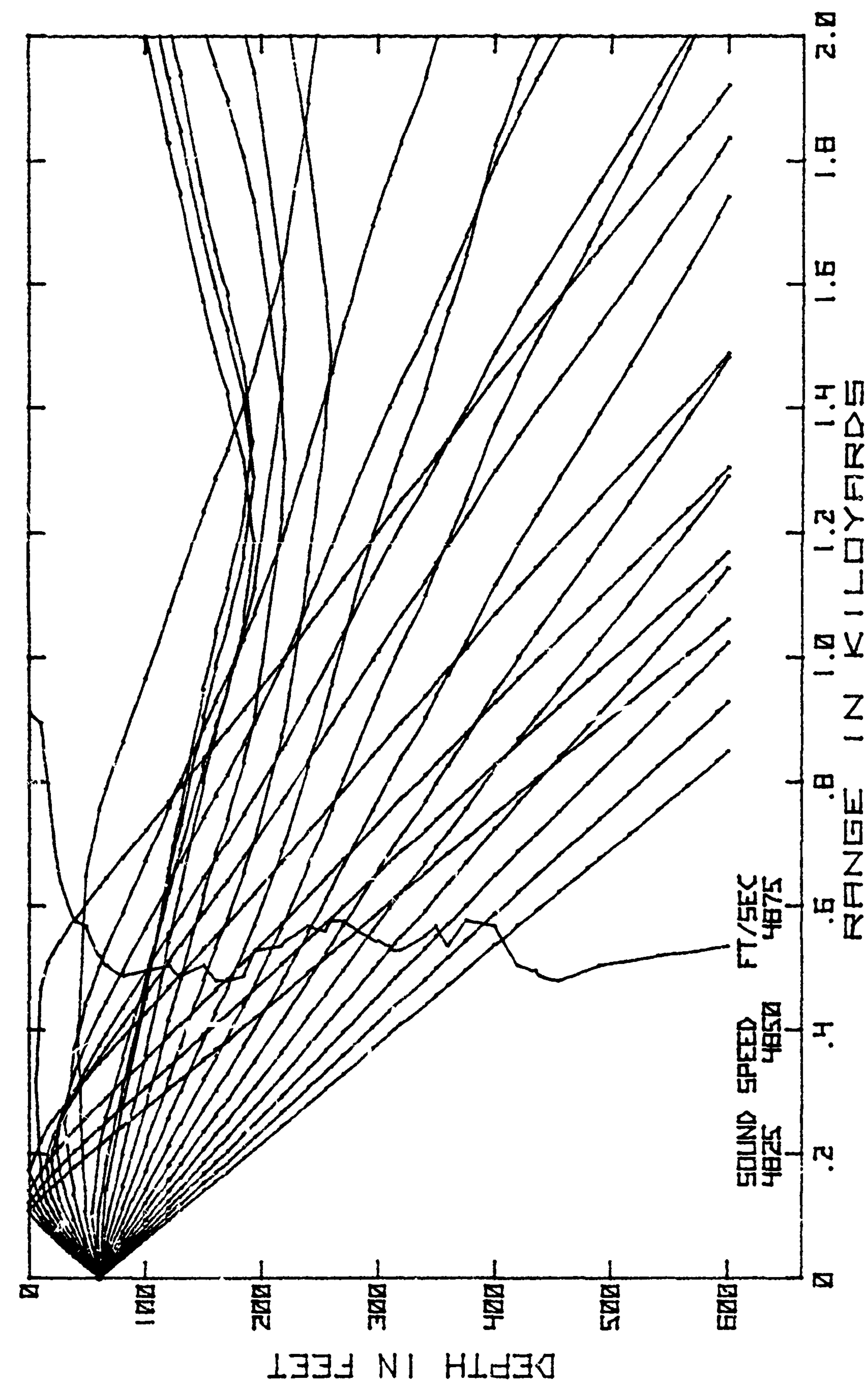

FIG. C-60. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 60 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

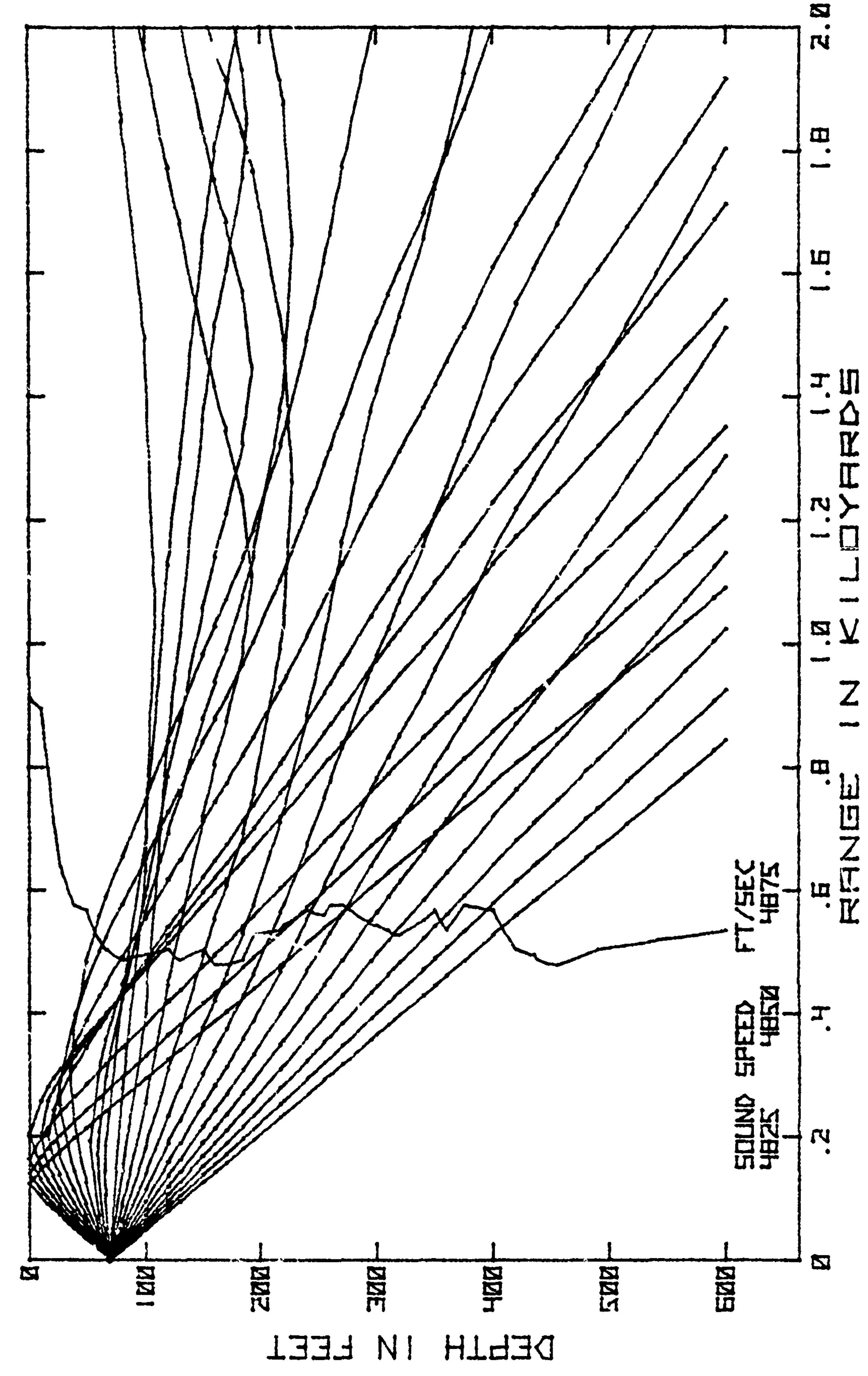

FIG. C-61. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 70 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

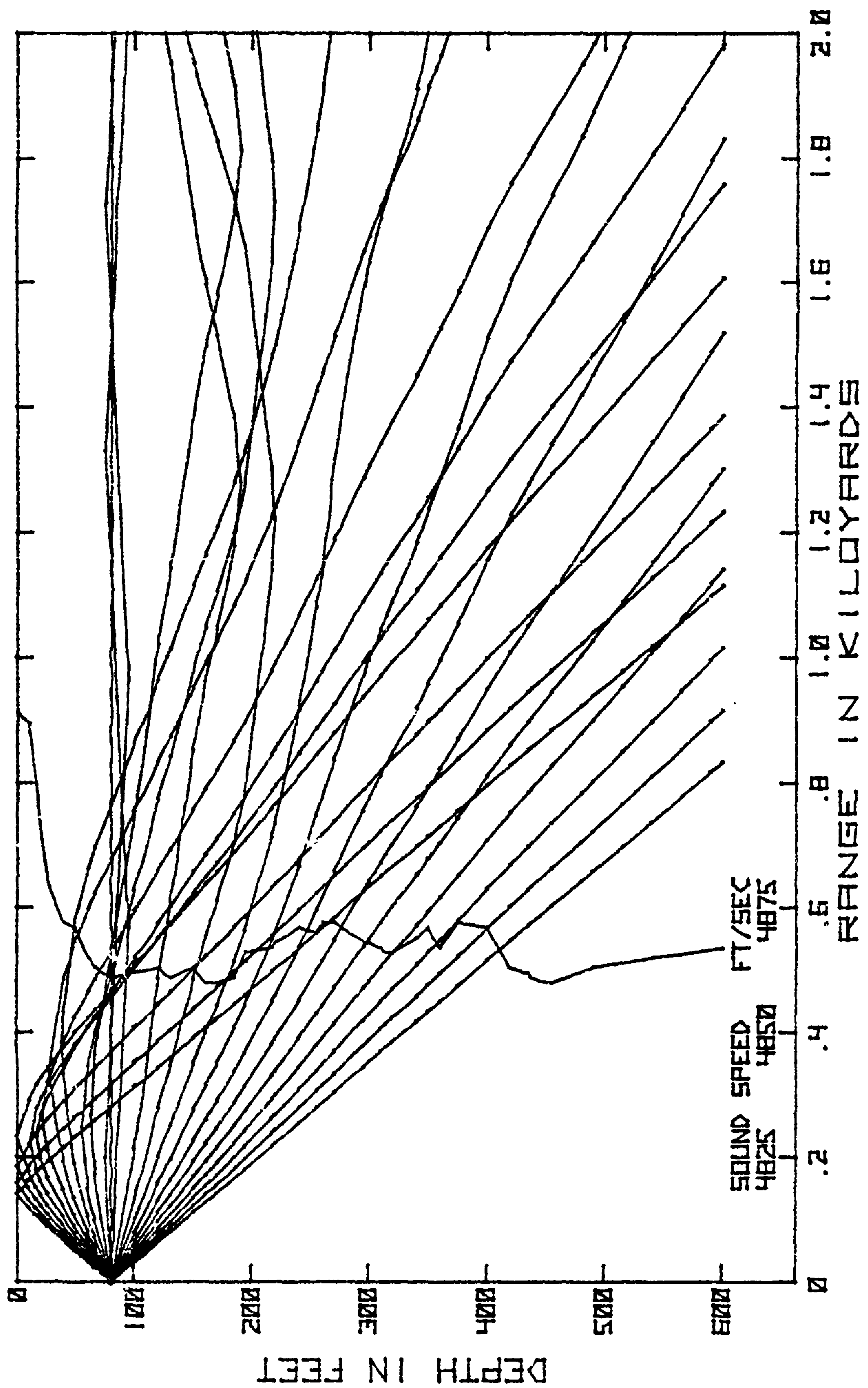

FIG. C-62. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 80 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

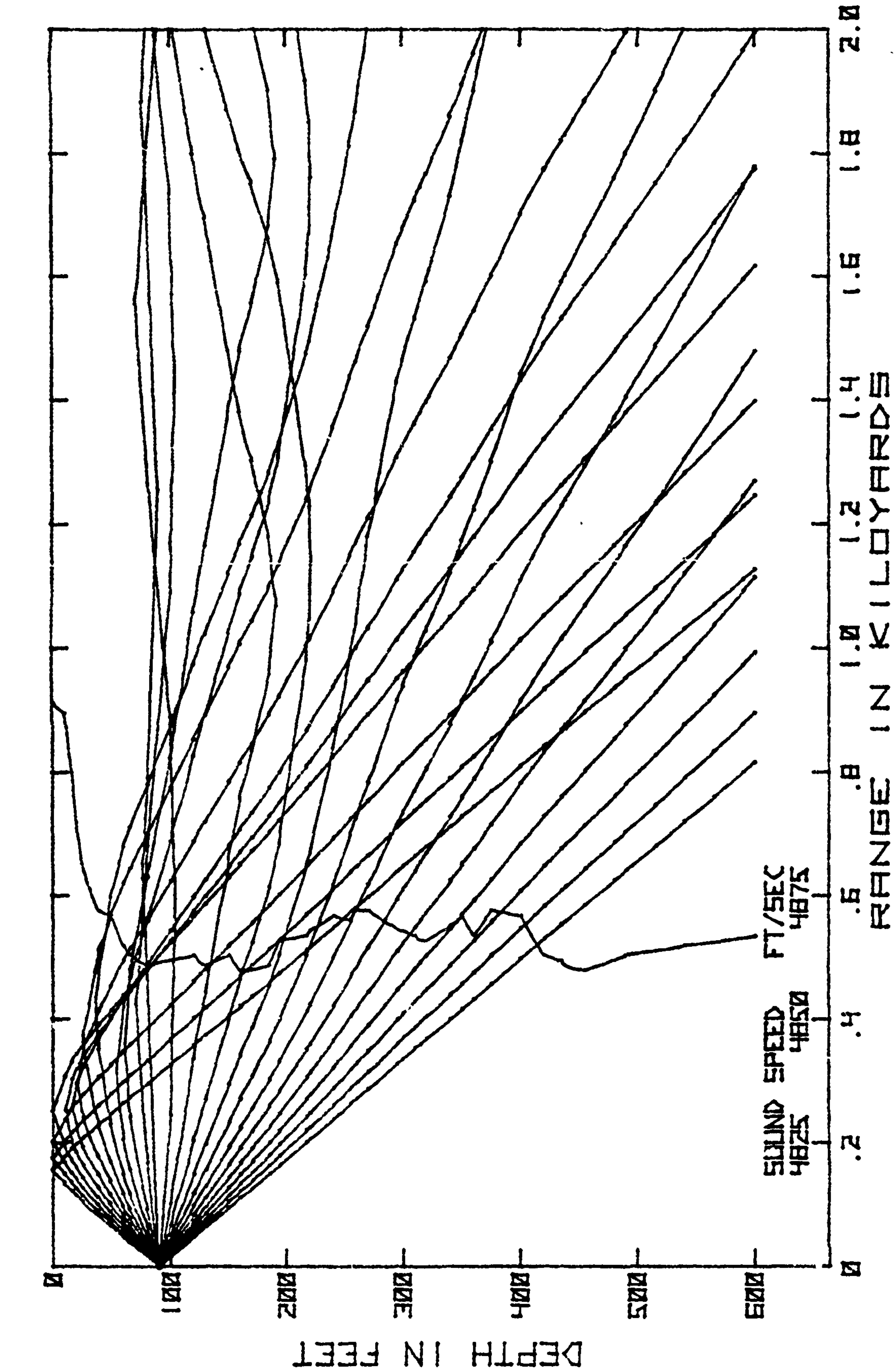

FIG. C-63. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 90 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

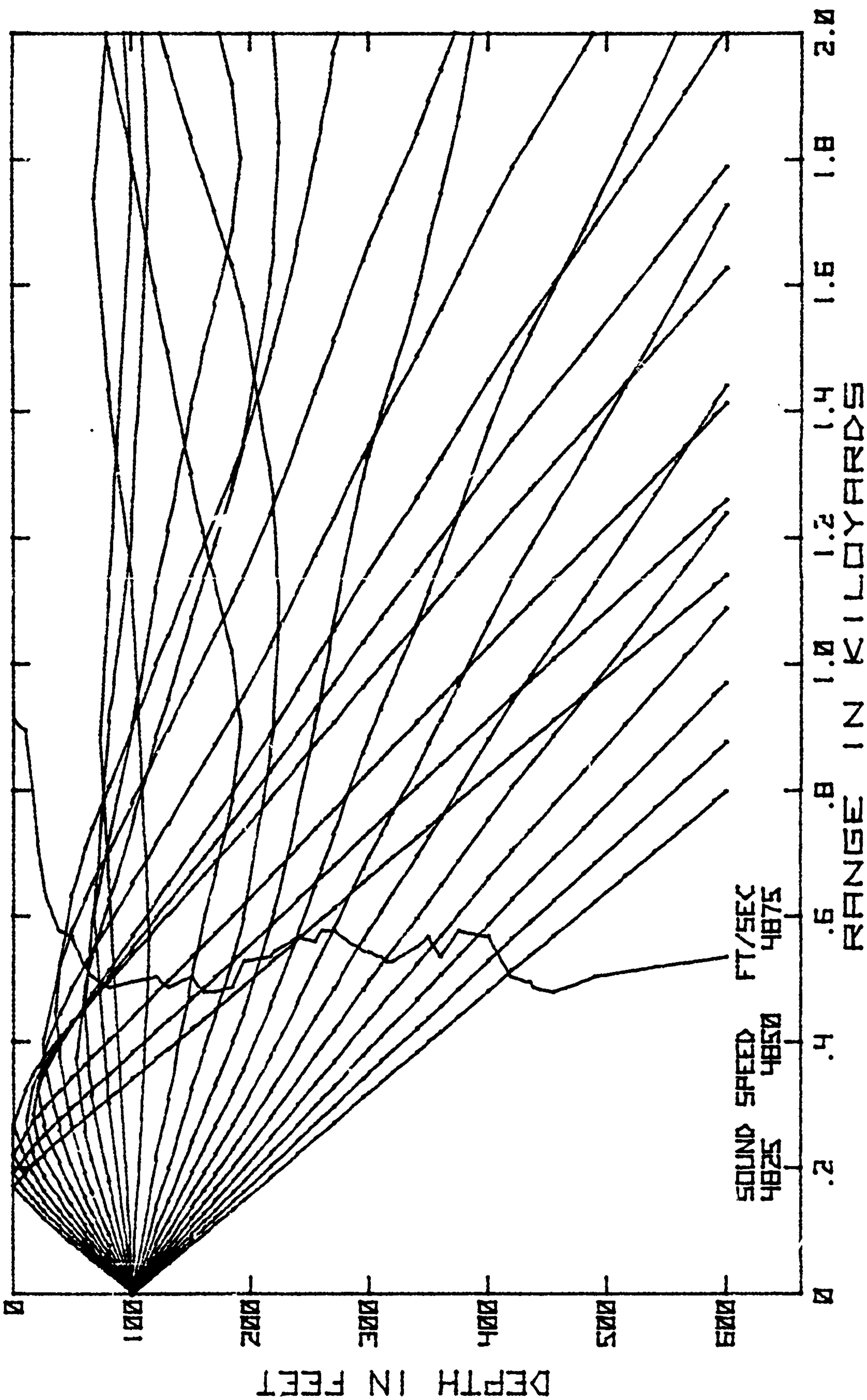

FIG. C-64. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 100 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

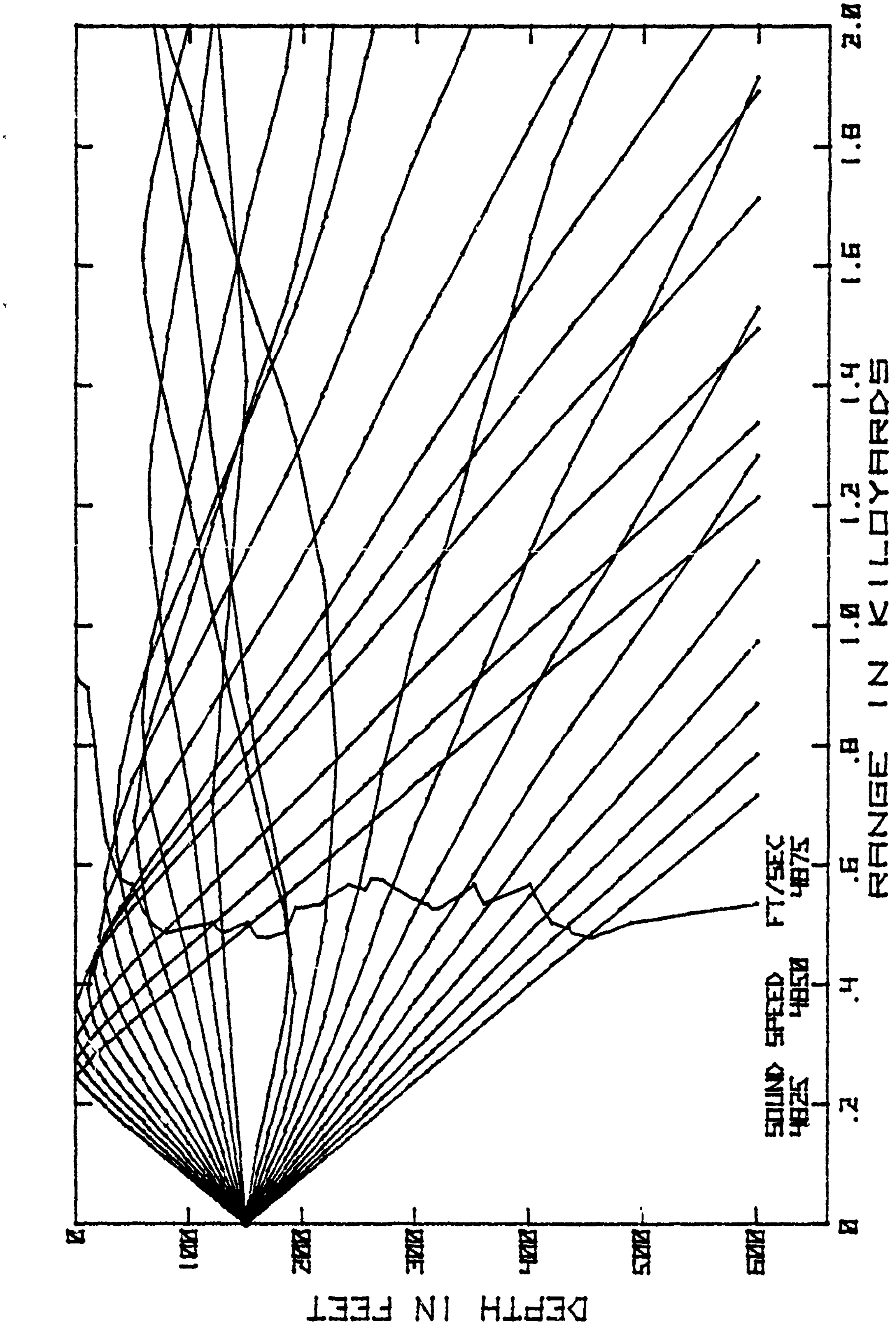

FIG. C-65. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 150 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

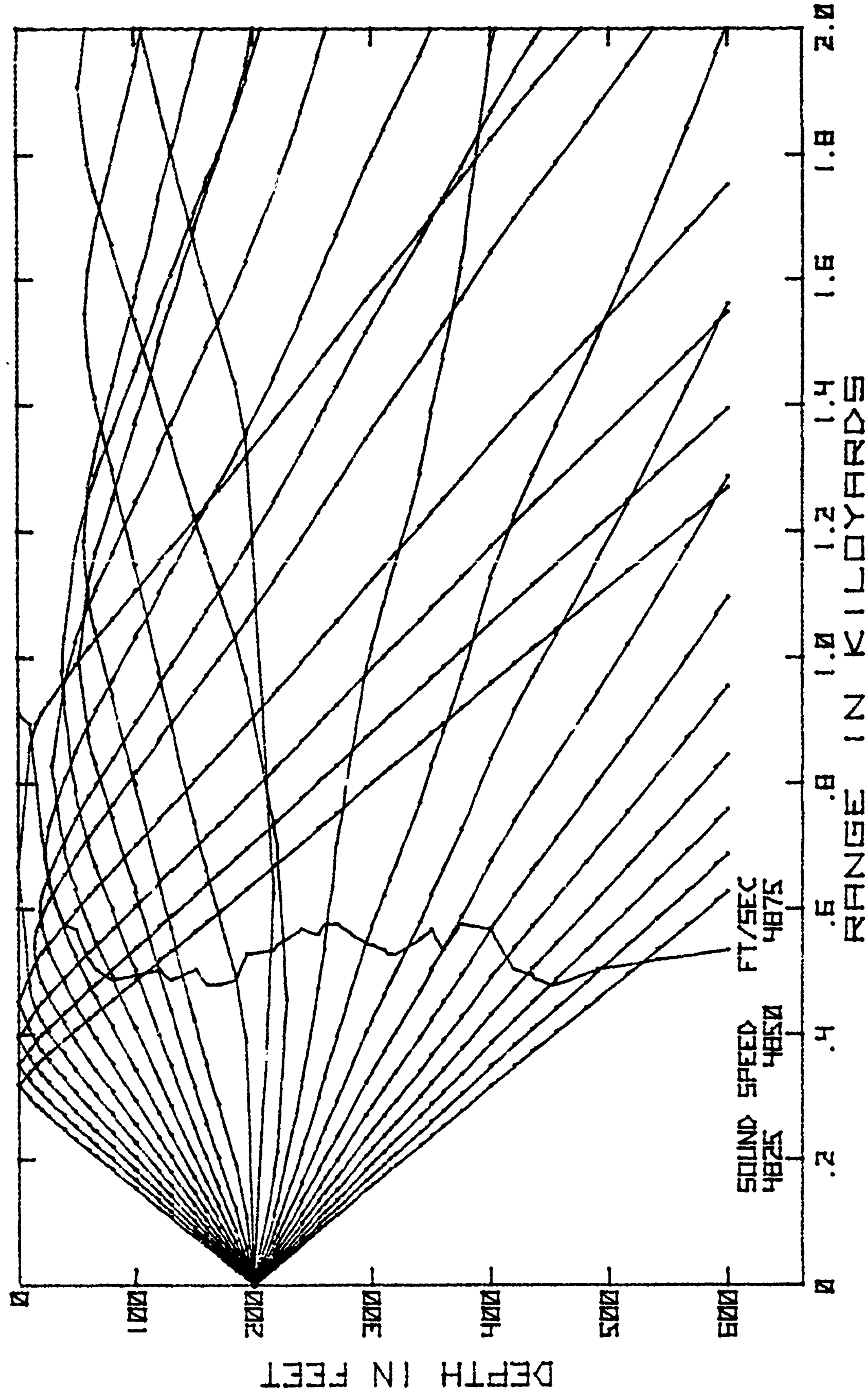

FIG. C-66. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 200 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

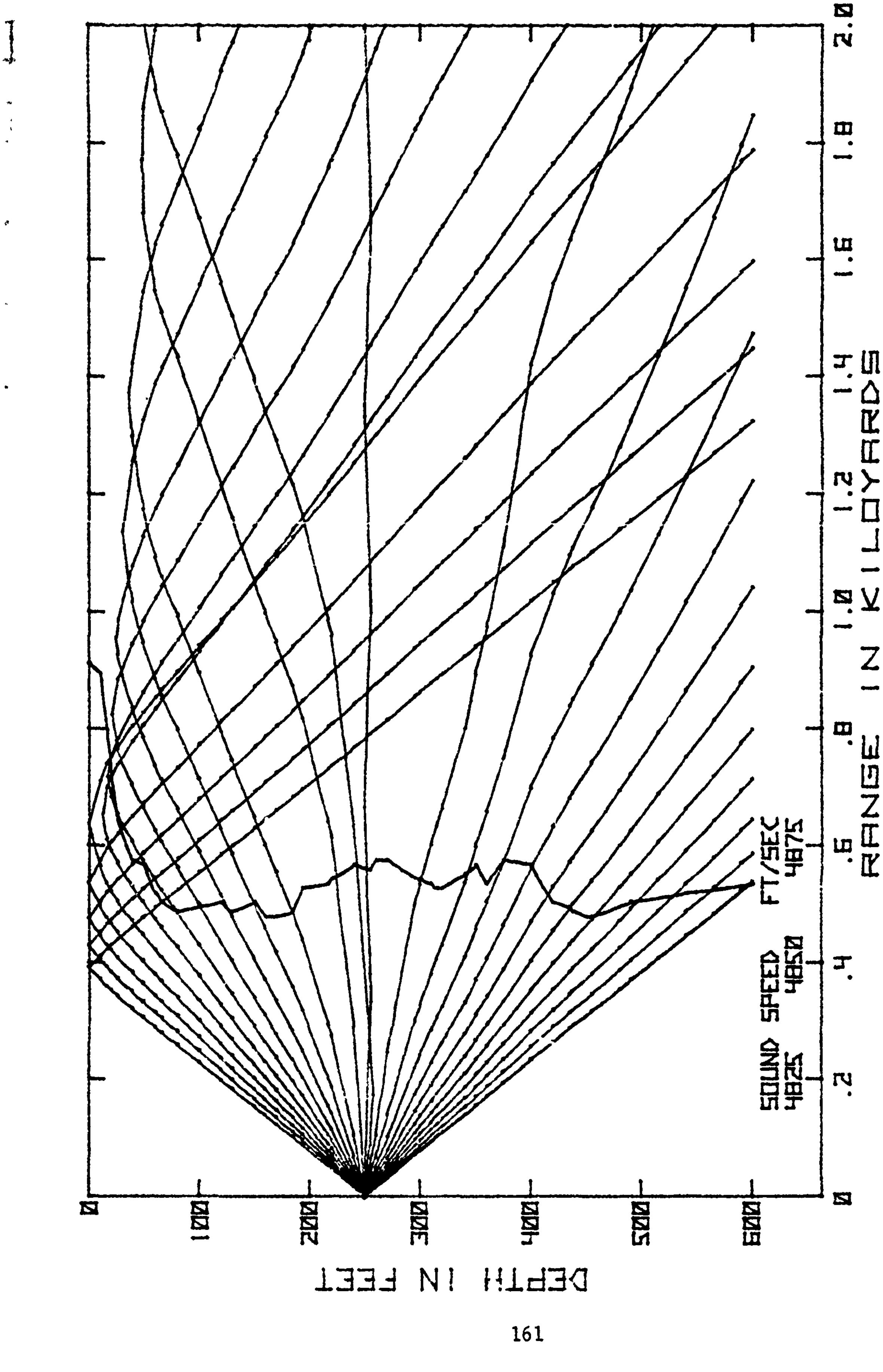

FIG. C-67. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 250 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

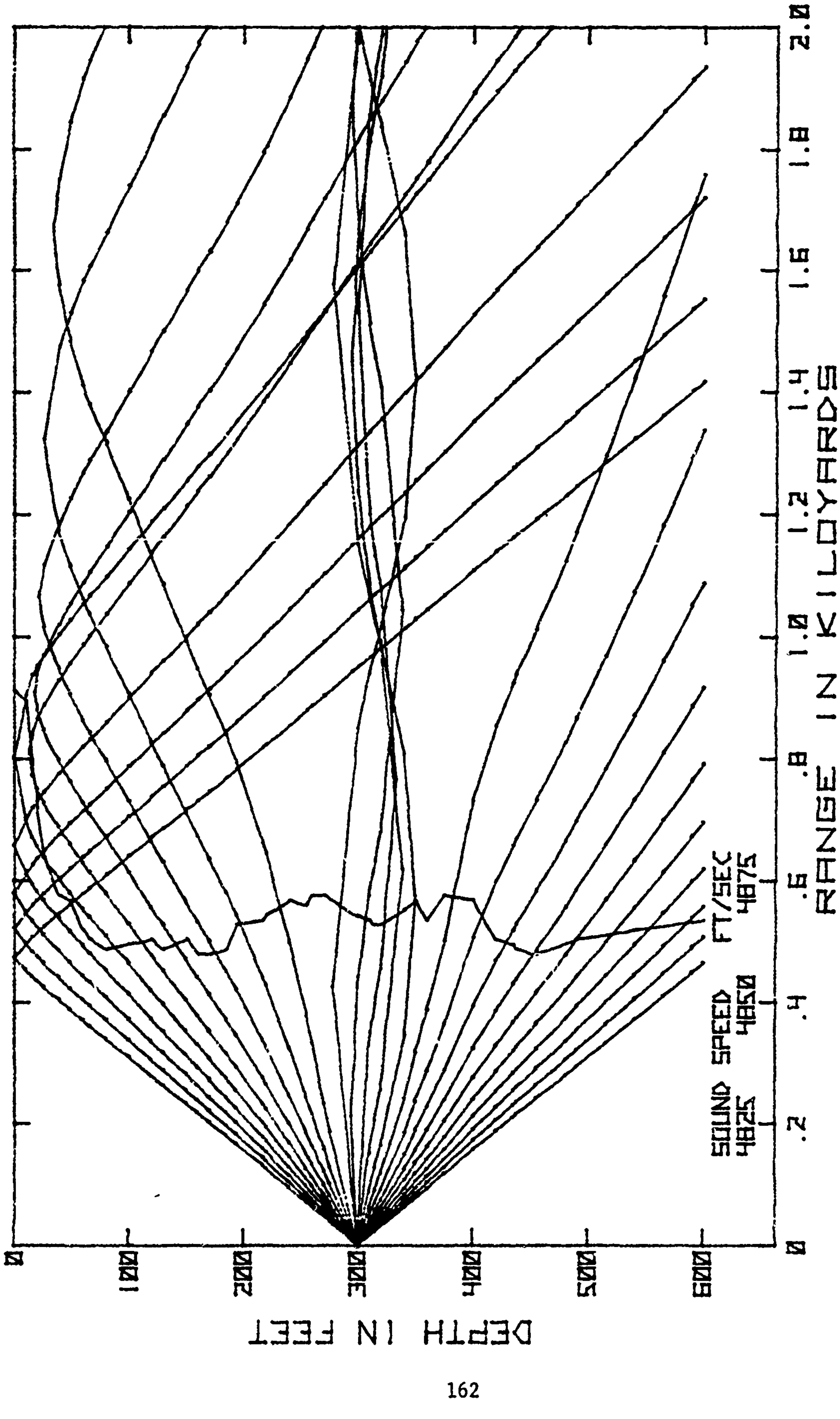

FIG. C-68. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 300 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

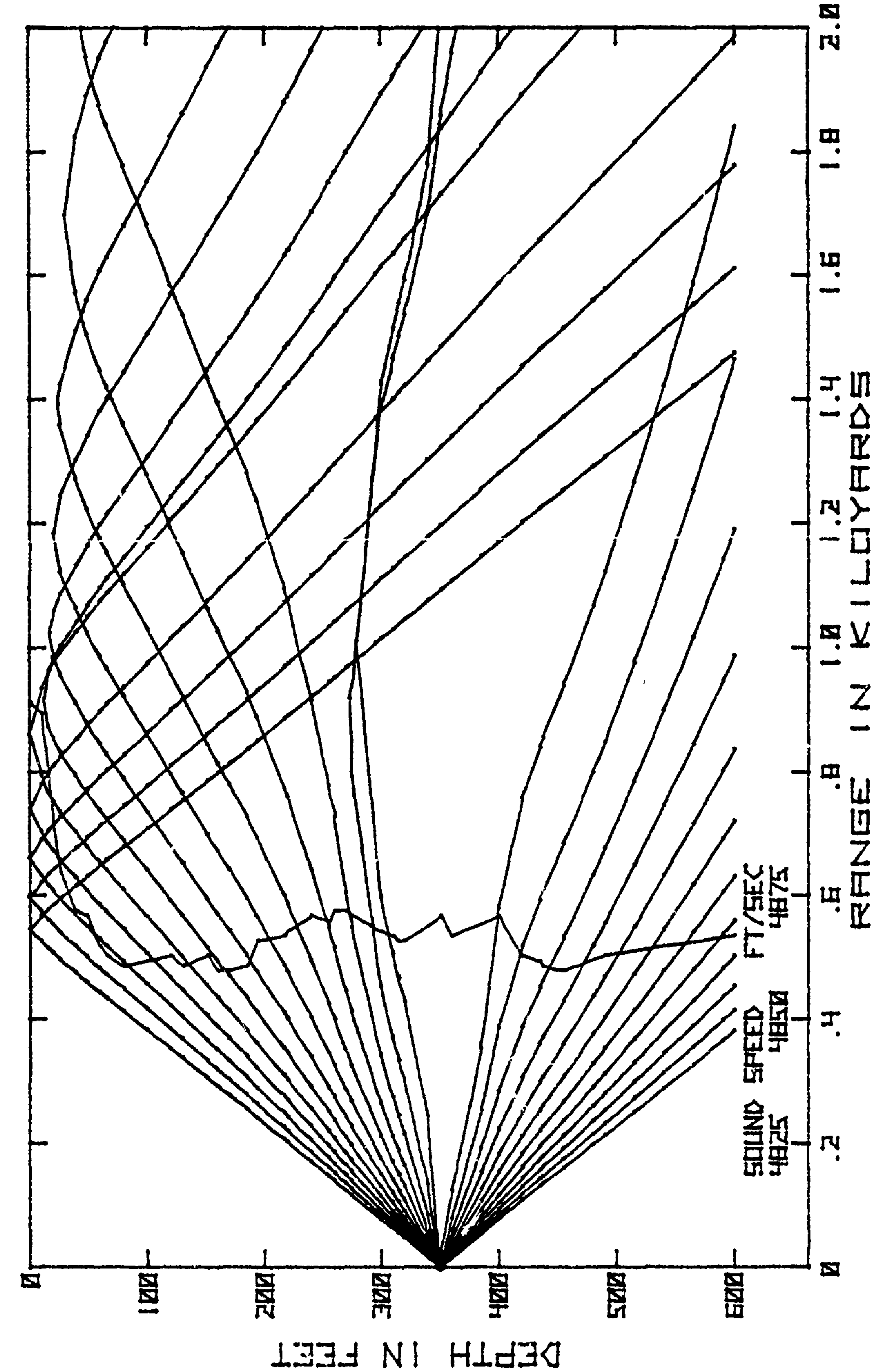

FIG. C-69. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 350 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

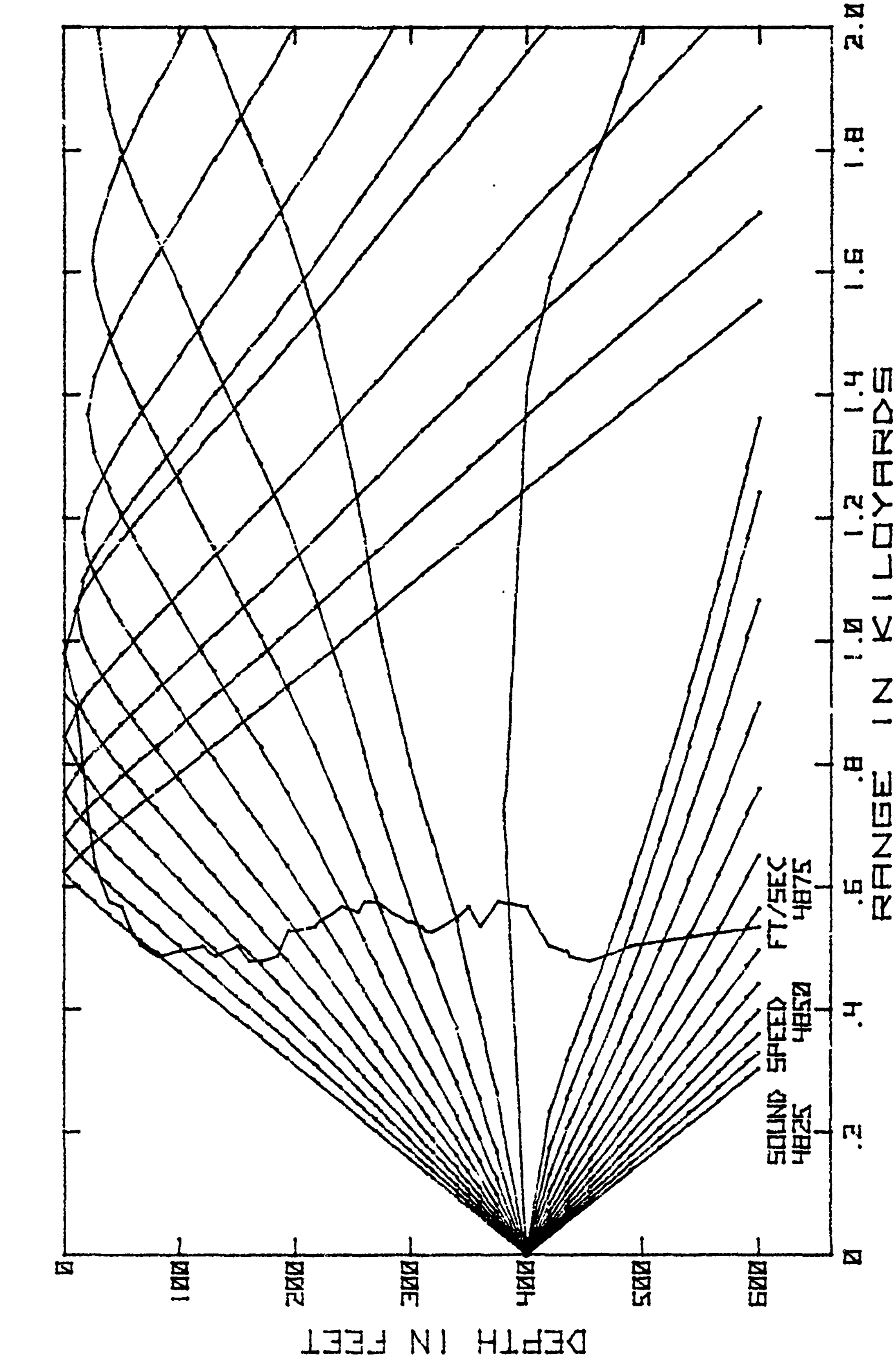

FIG. C-70. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 400 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

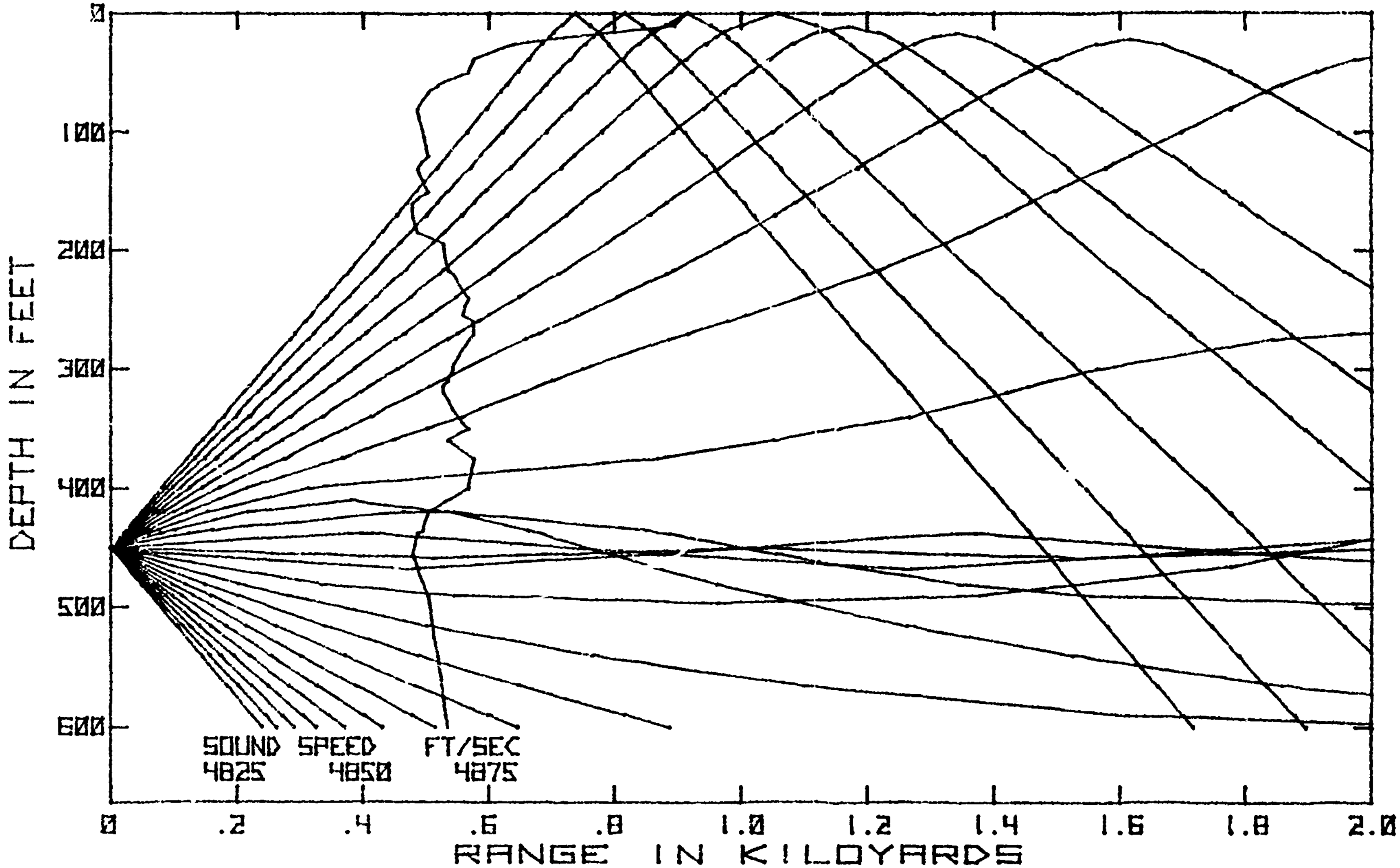

FIG. C-71. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 450 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

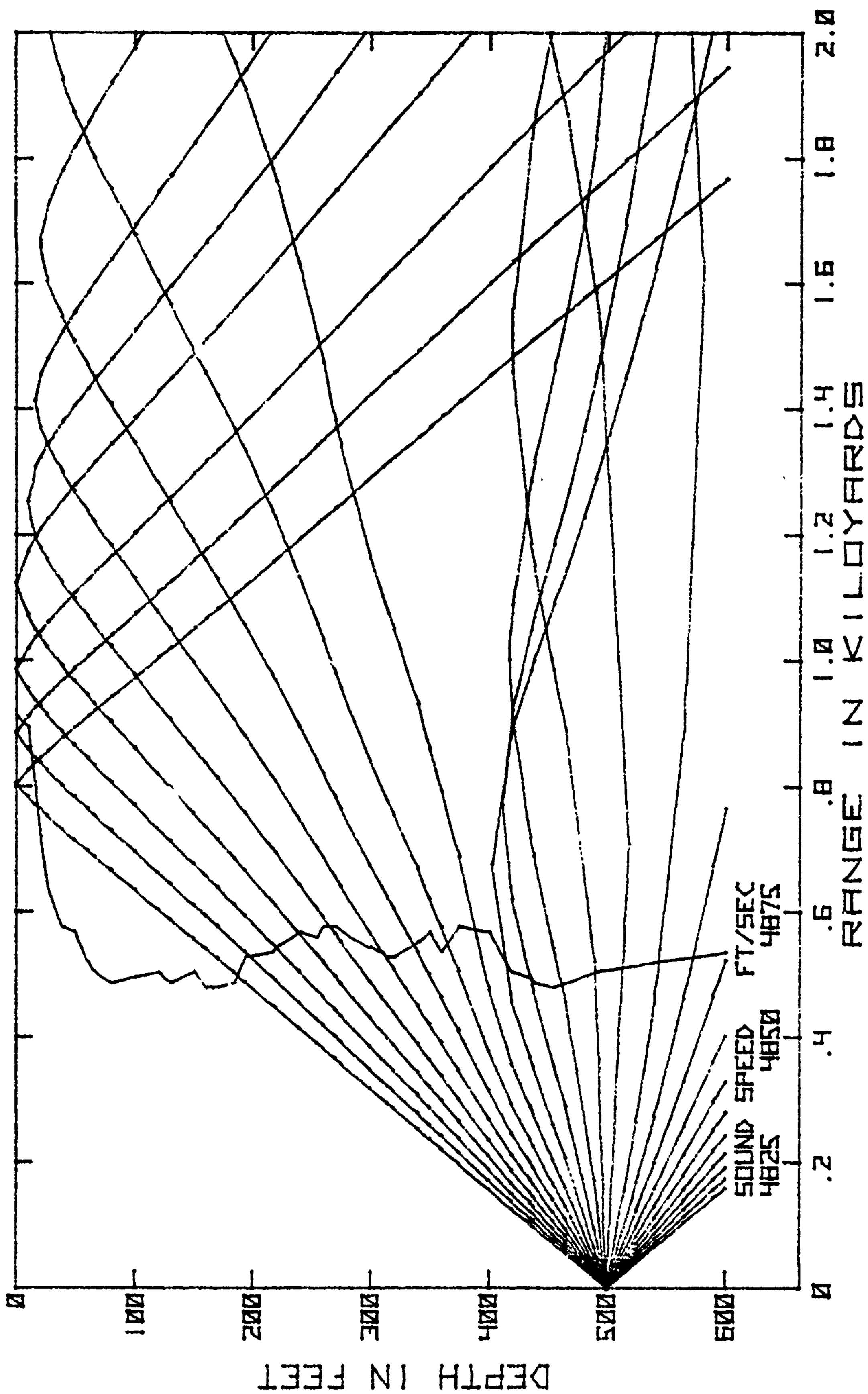

FIG. C-72. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 500 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

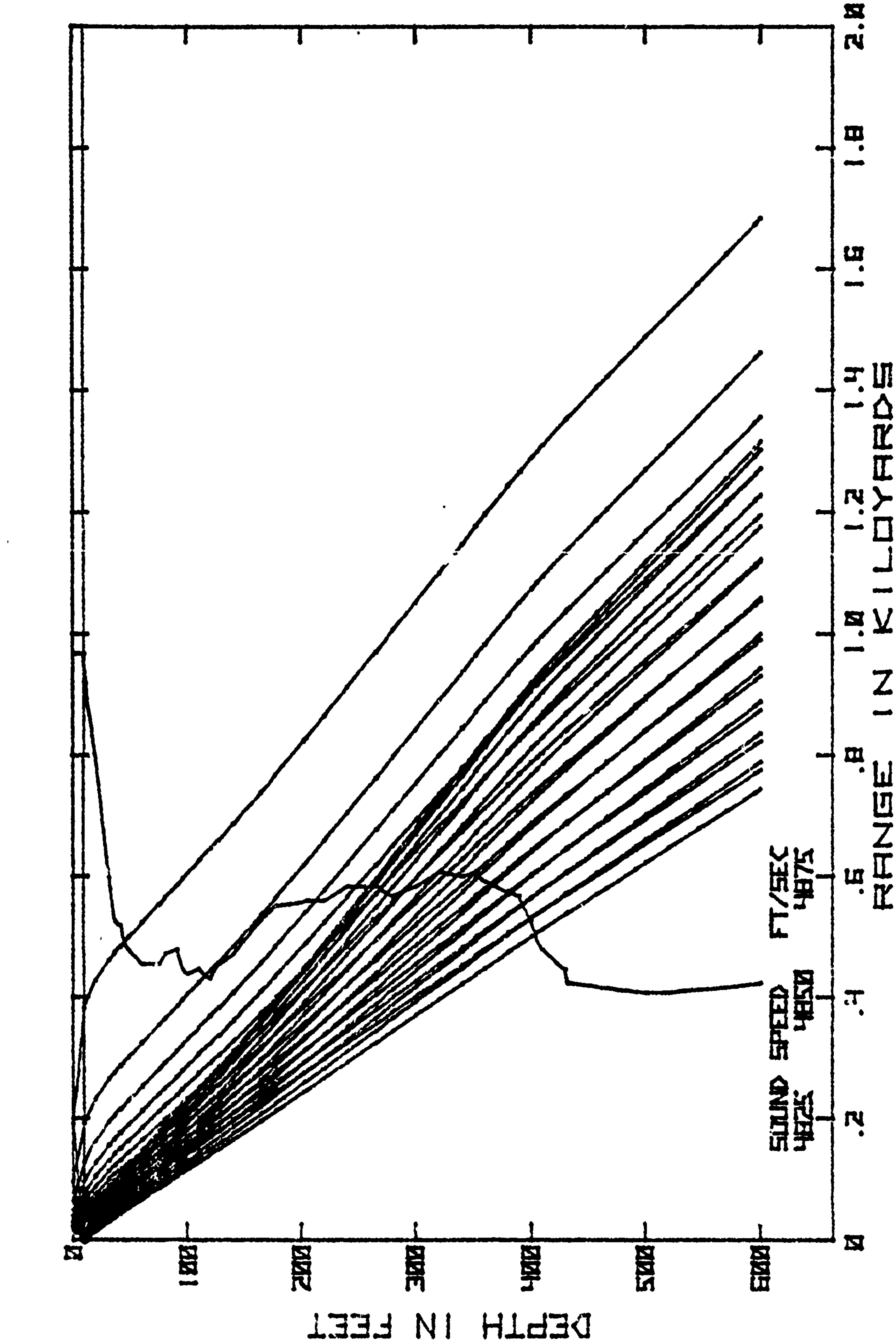

FIG. C-73. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 10 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

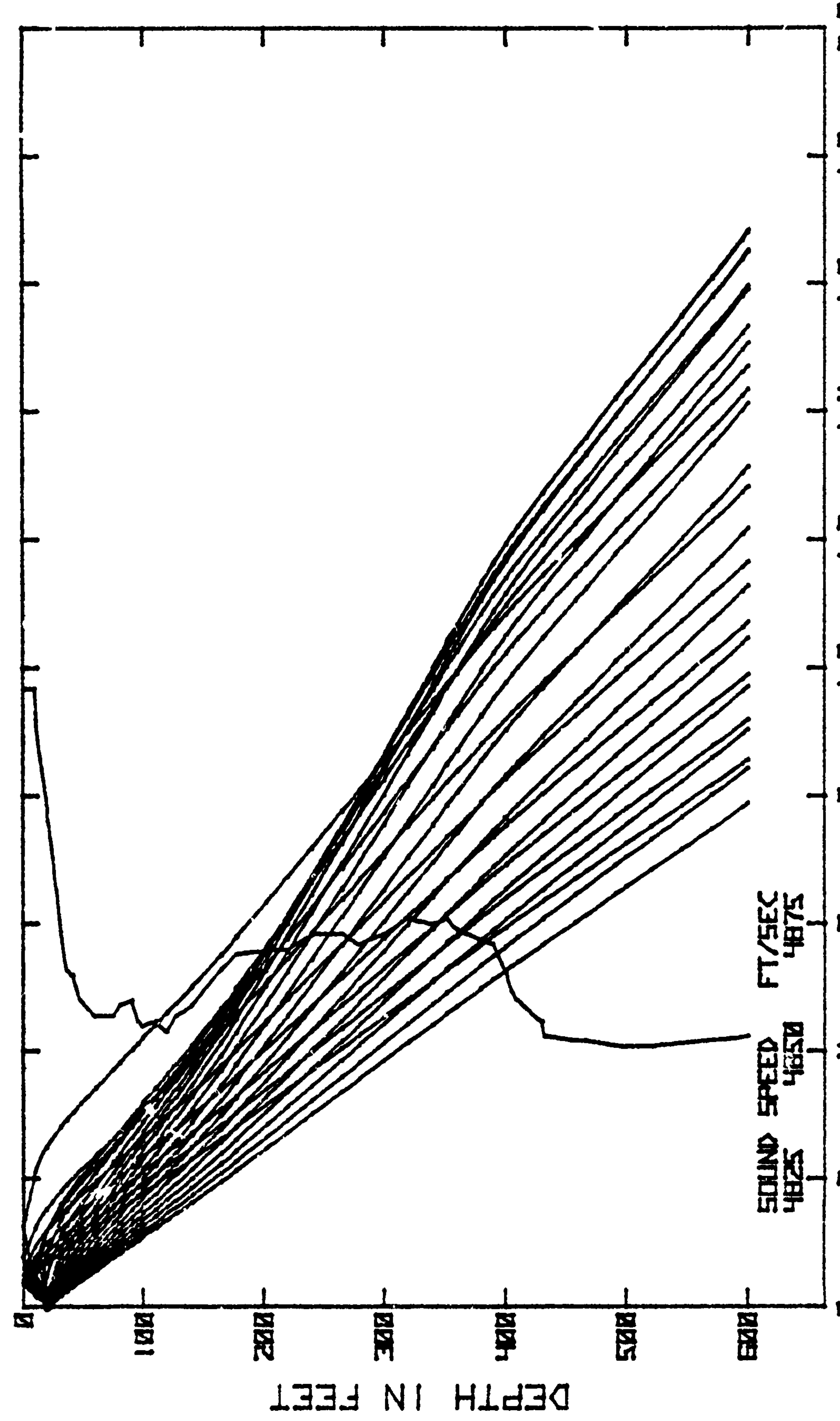

FIG. C-74. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 20 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

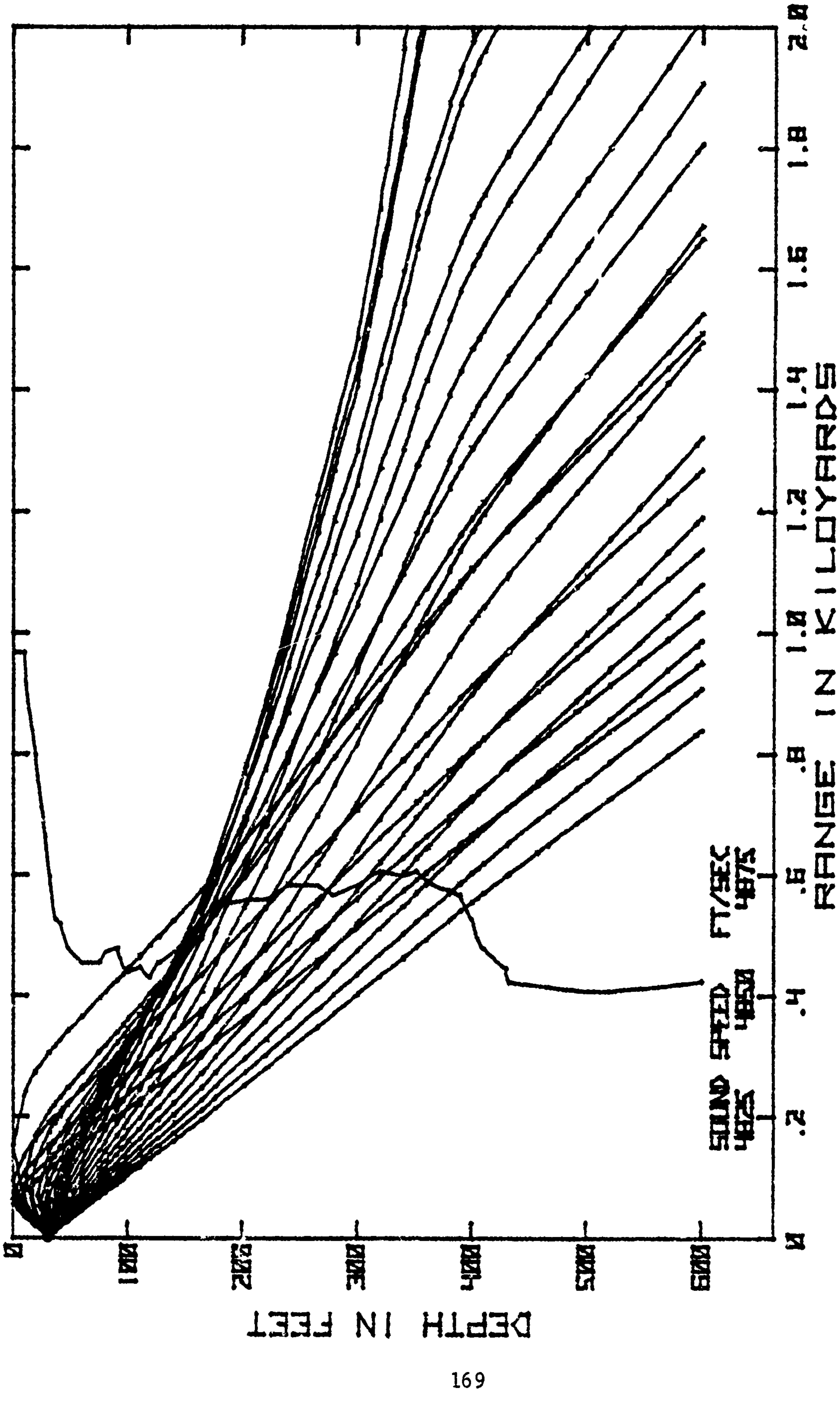

FIG. C-75. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 30 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

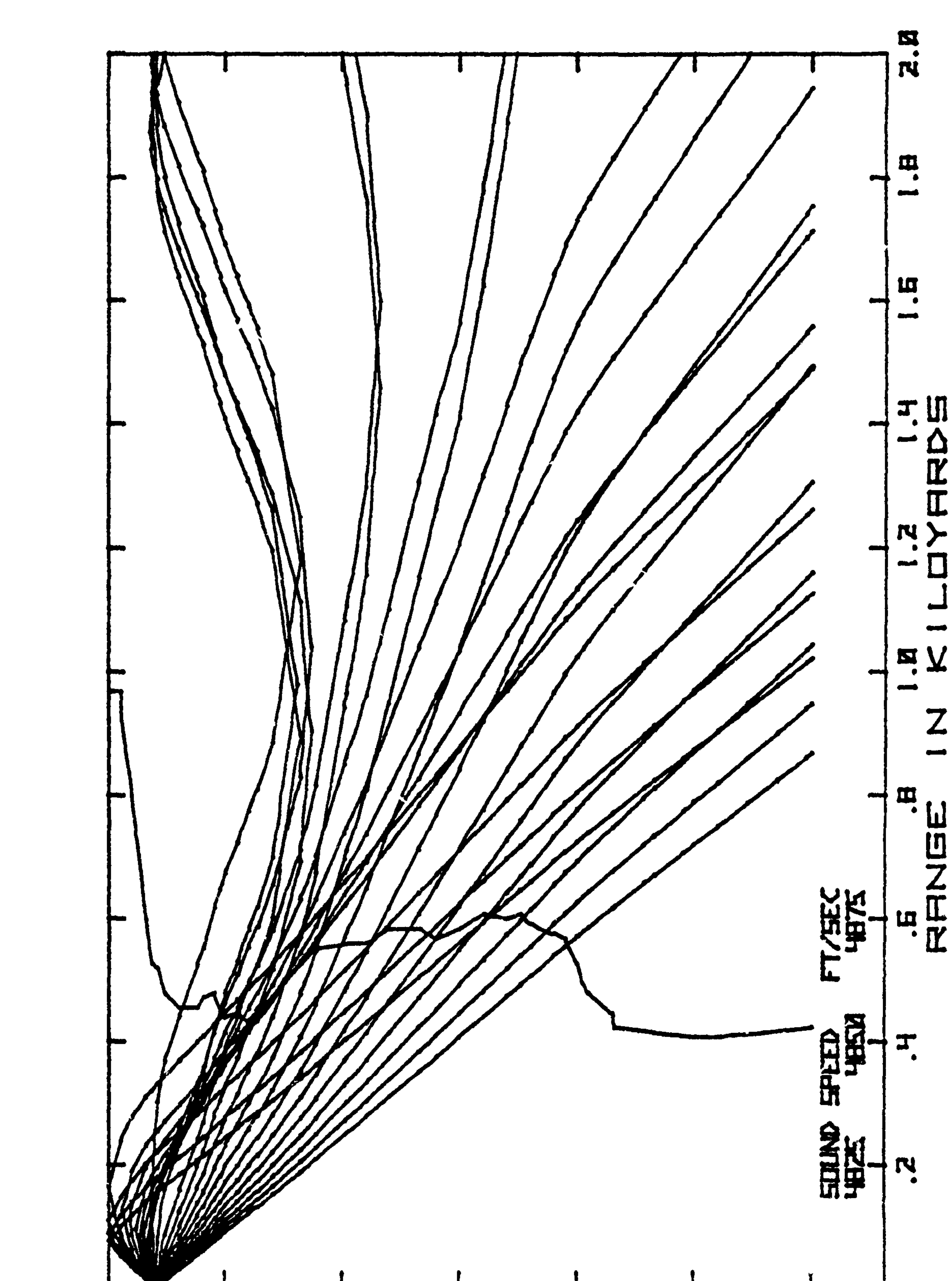

FIG. C-76. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 40 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

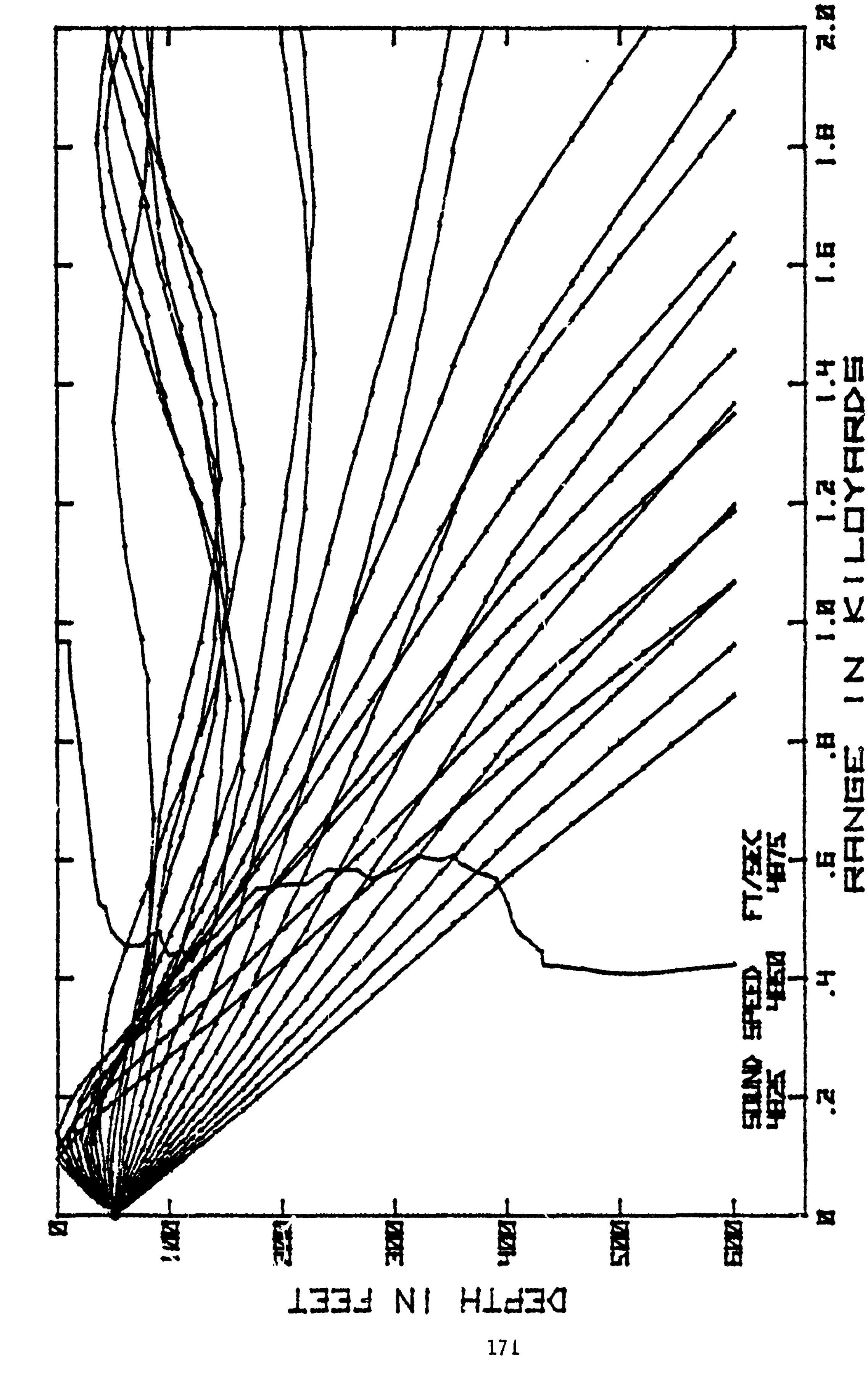

FIG. C-77. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 50 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

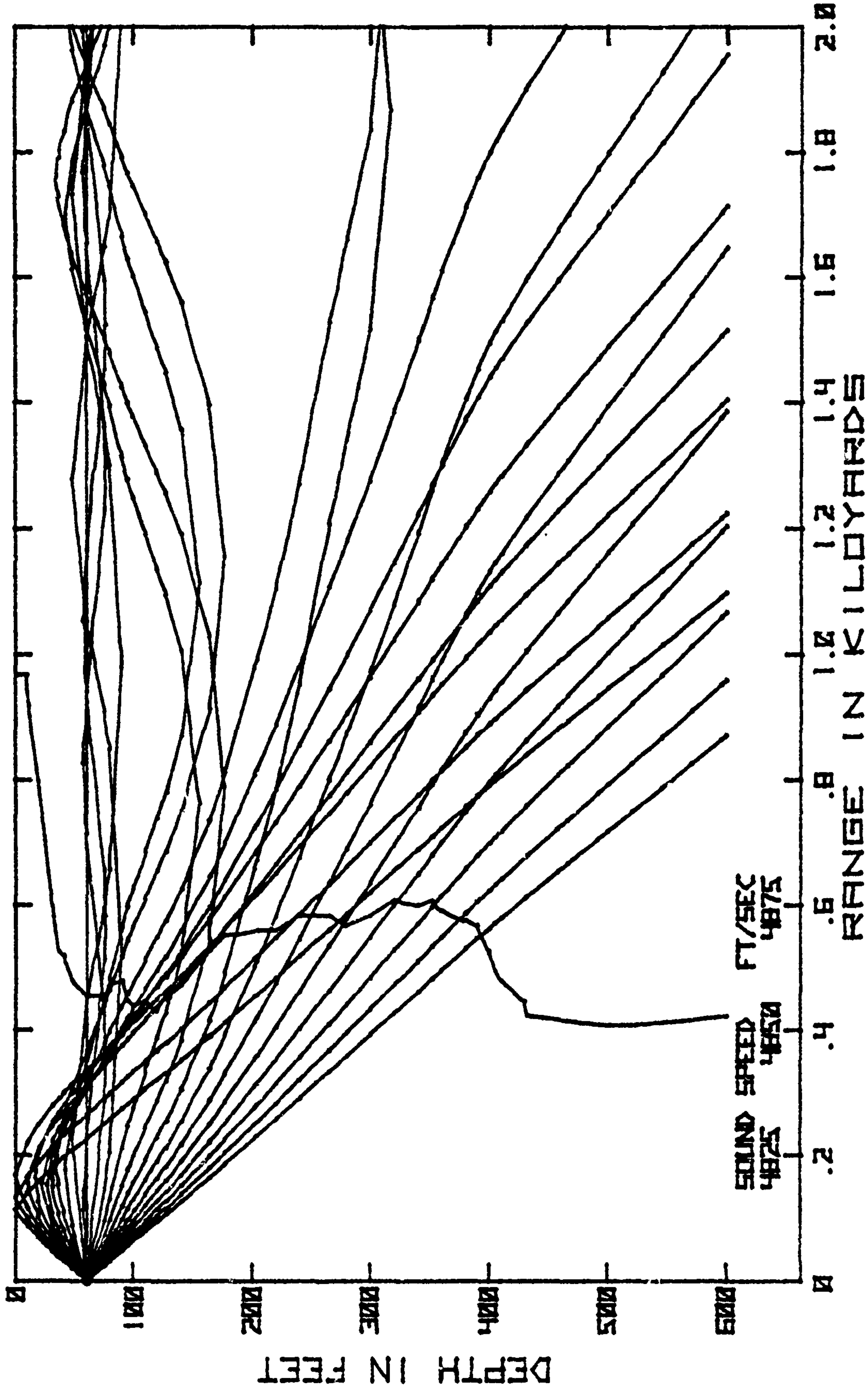

FIG. C-78. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 60 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

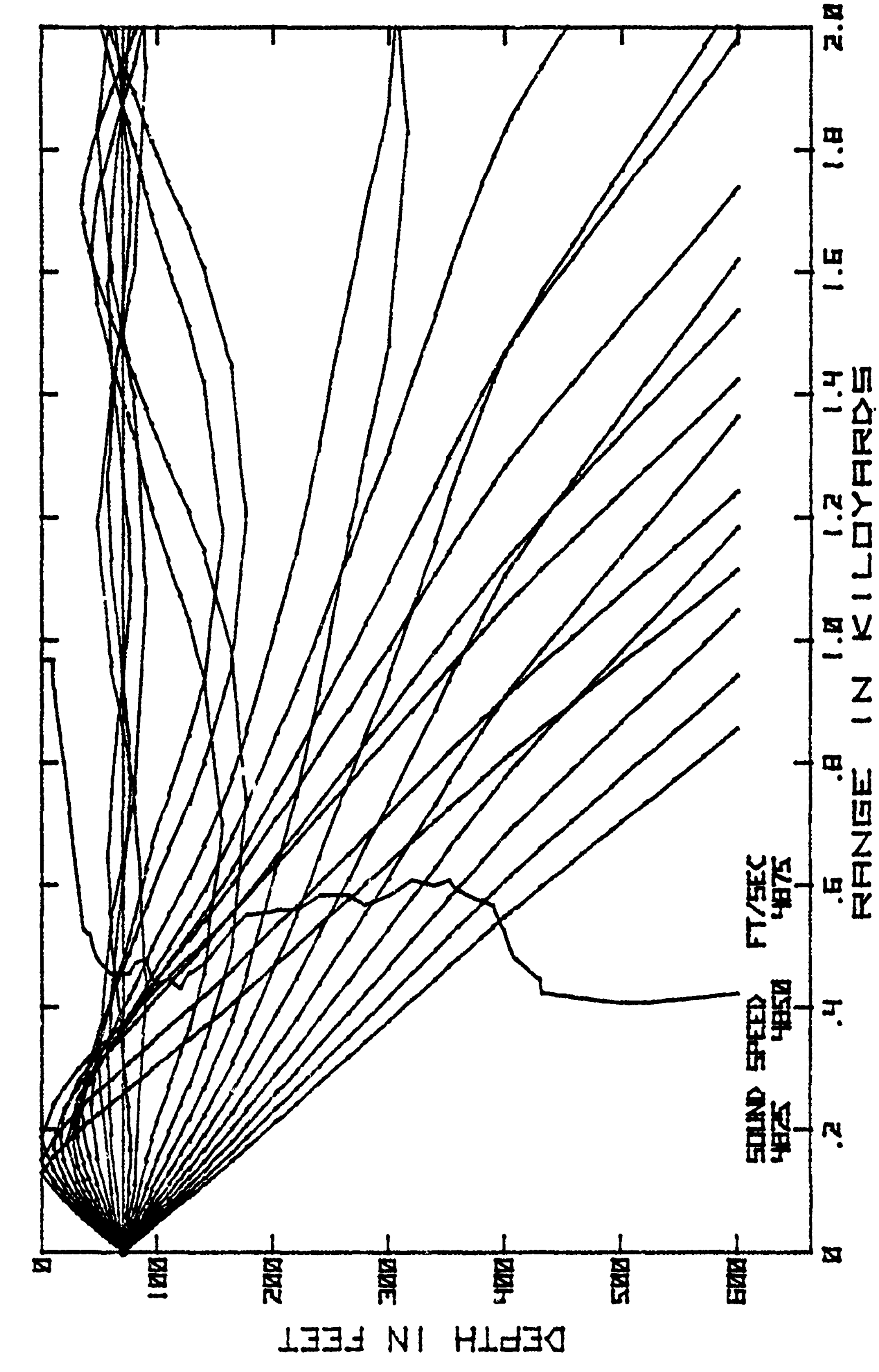

FIG. C-79. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 70 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

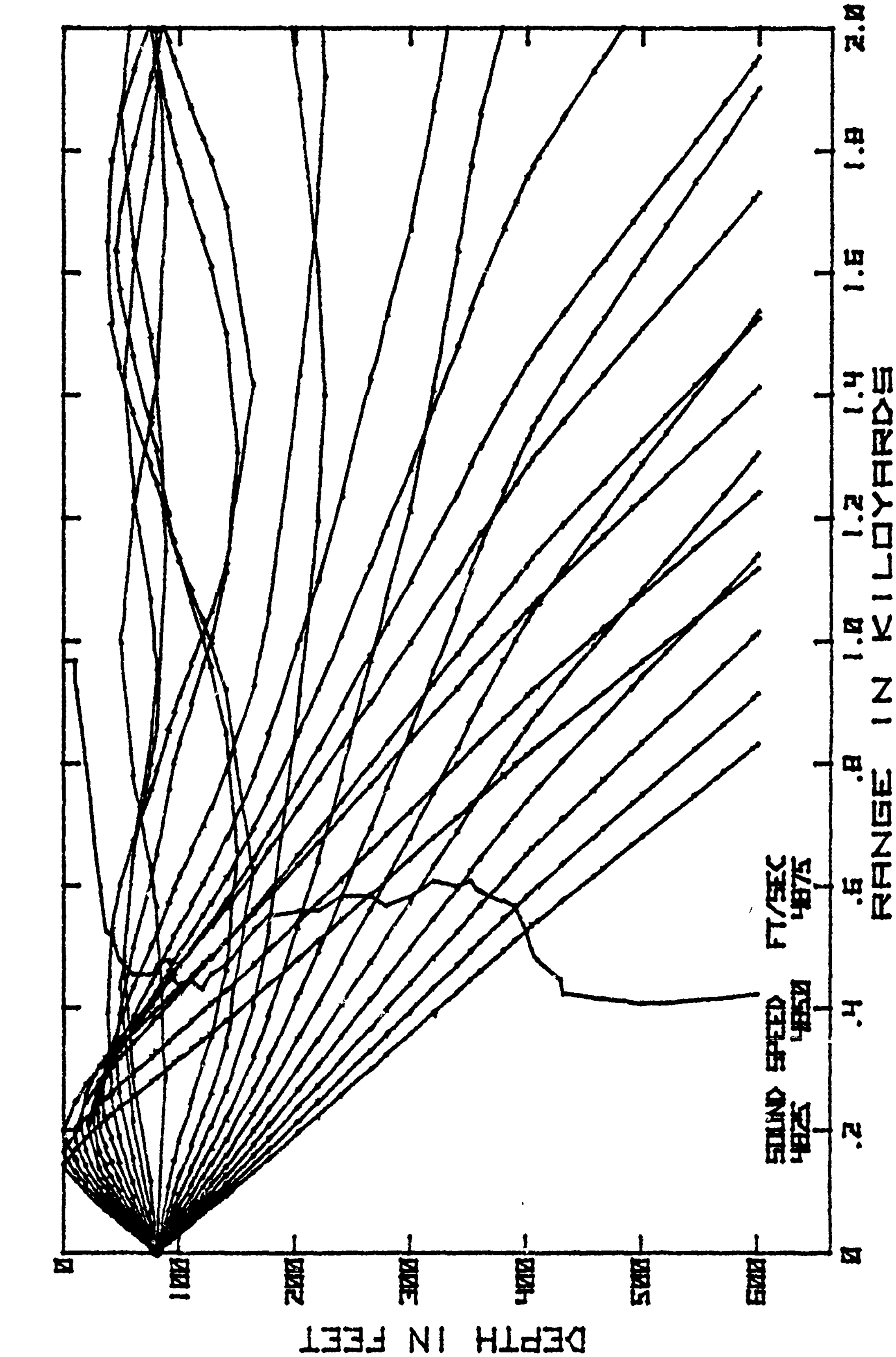

FIG. C-80. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 80 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

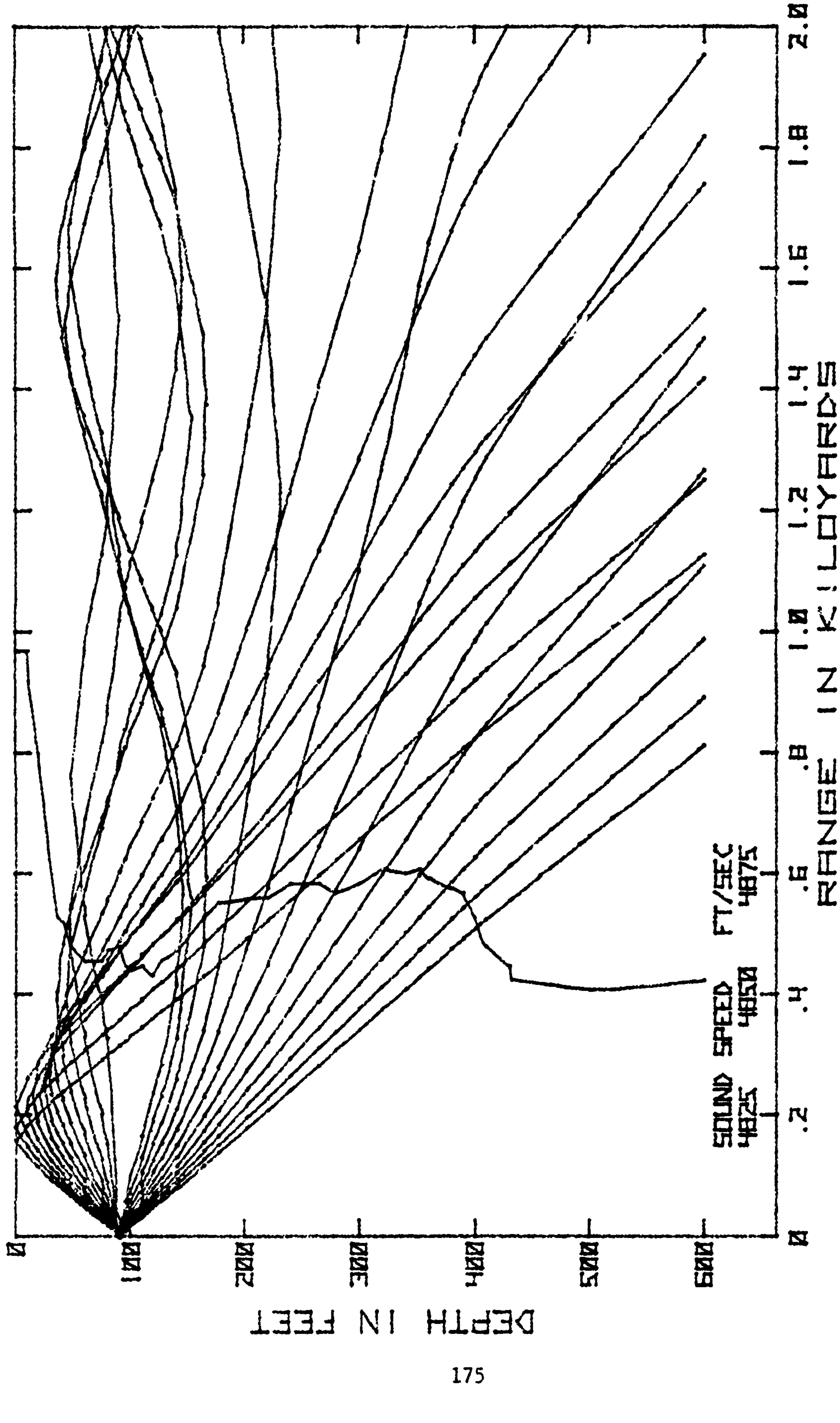

FIG. C-81. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 90 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

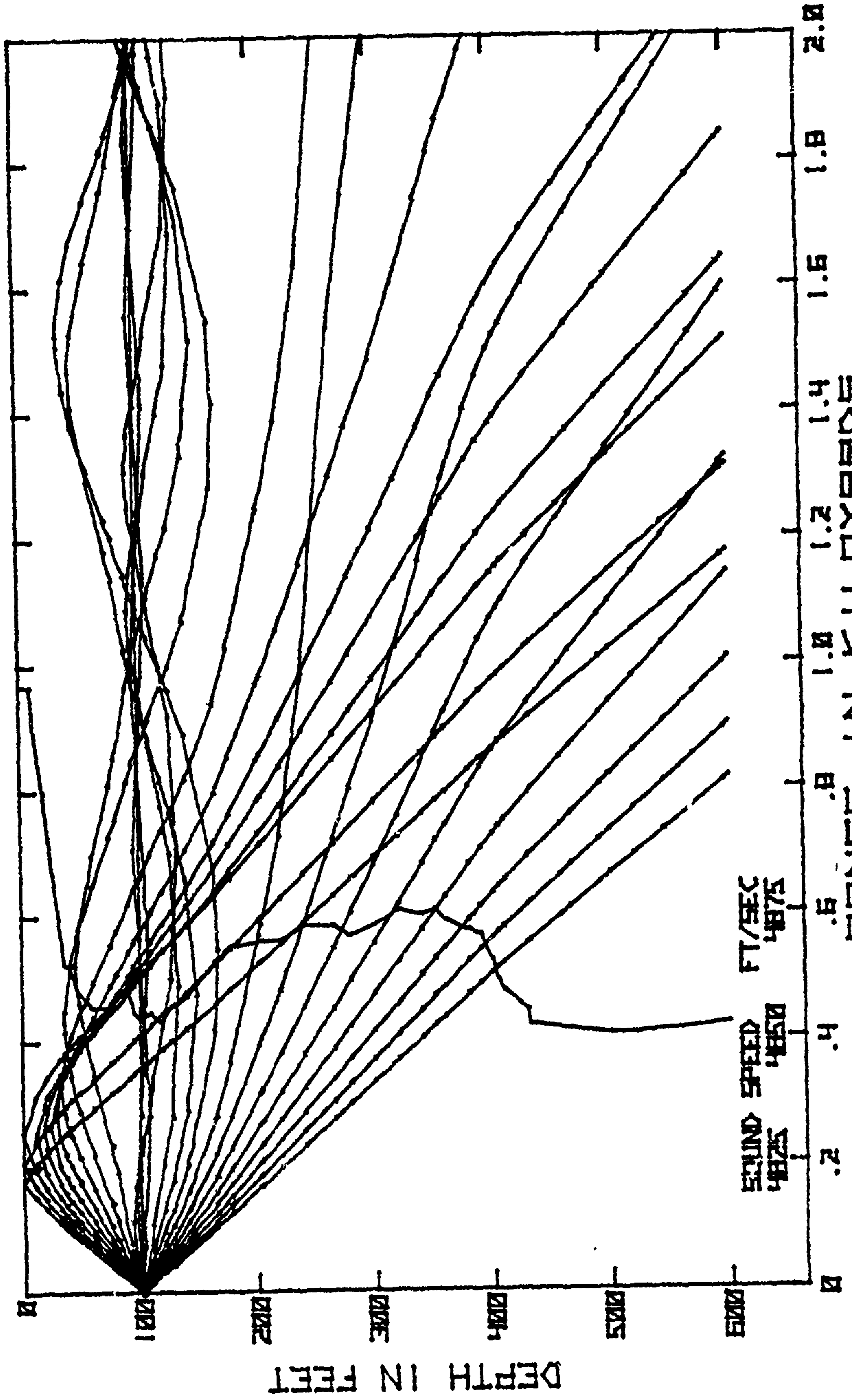

FIG. C-82. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 100 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

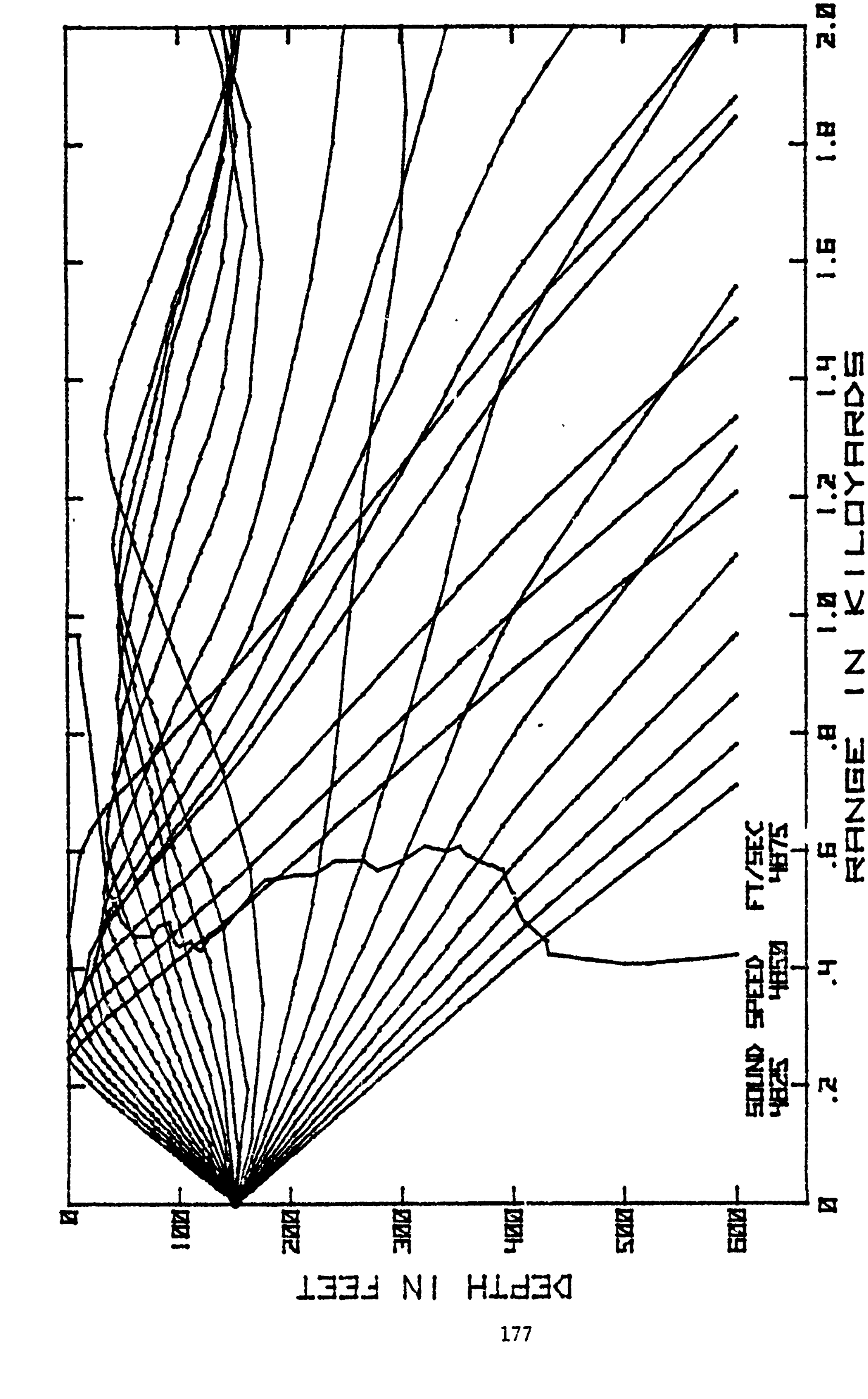

FIG. C-83. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 150 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

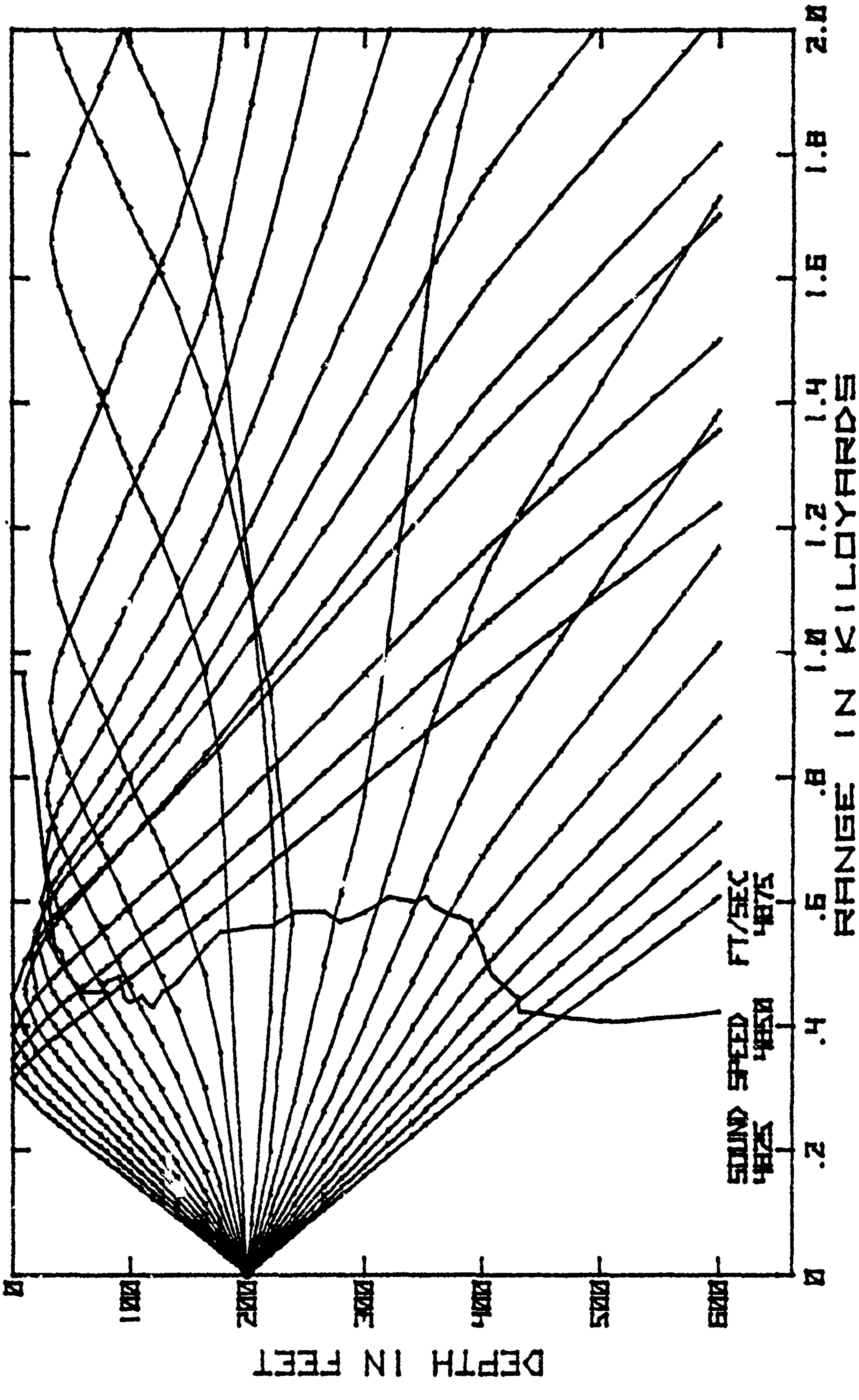

FIG. C-84. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 200 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

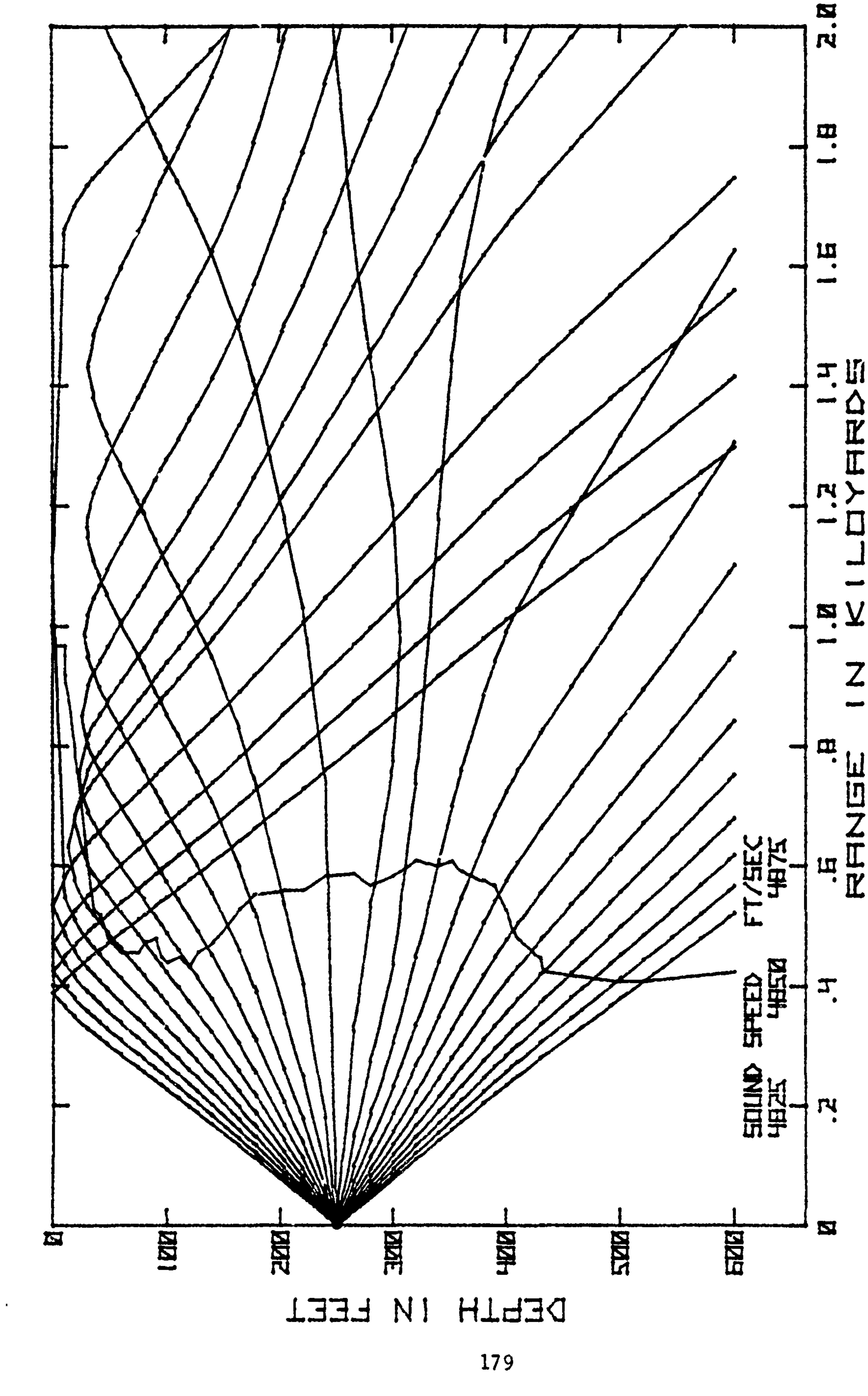

FIG. C-85. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 250 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

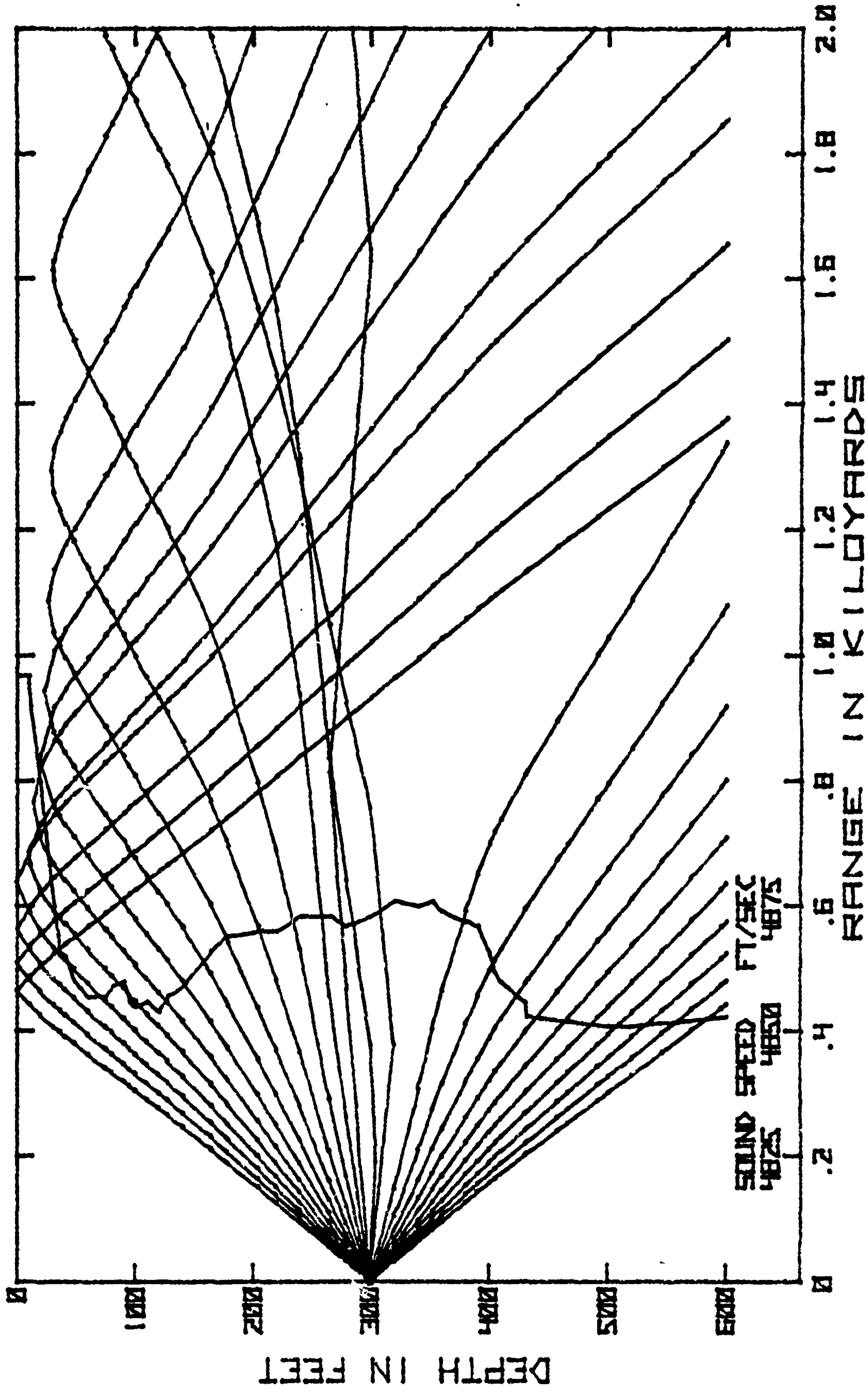

FIG. C-86. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 300 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

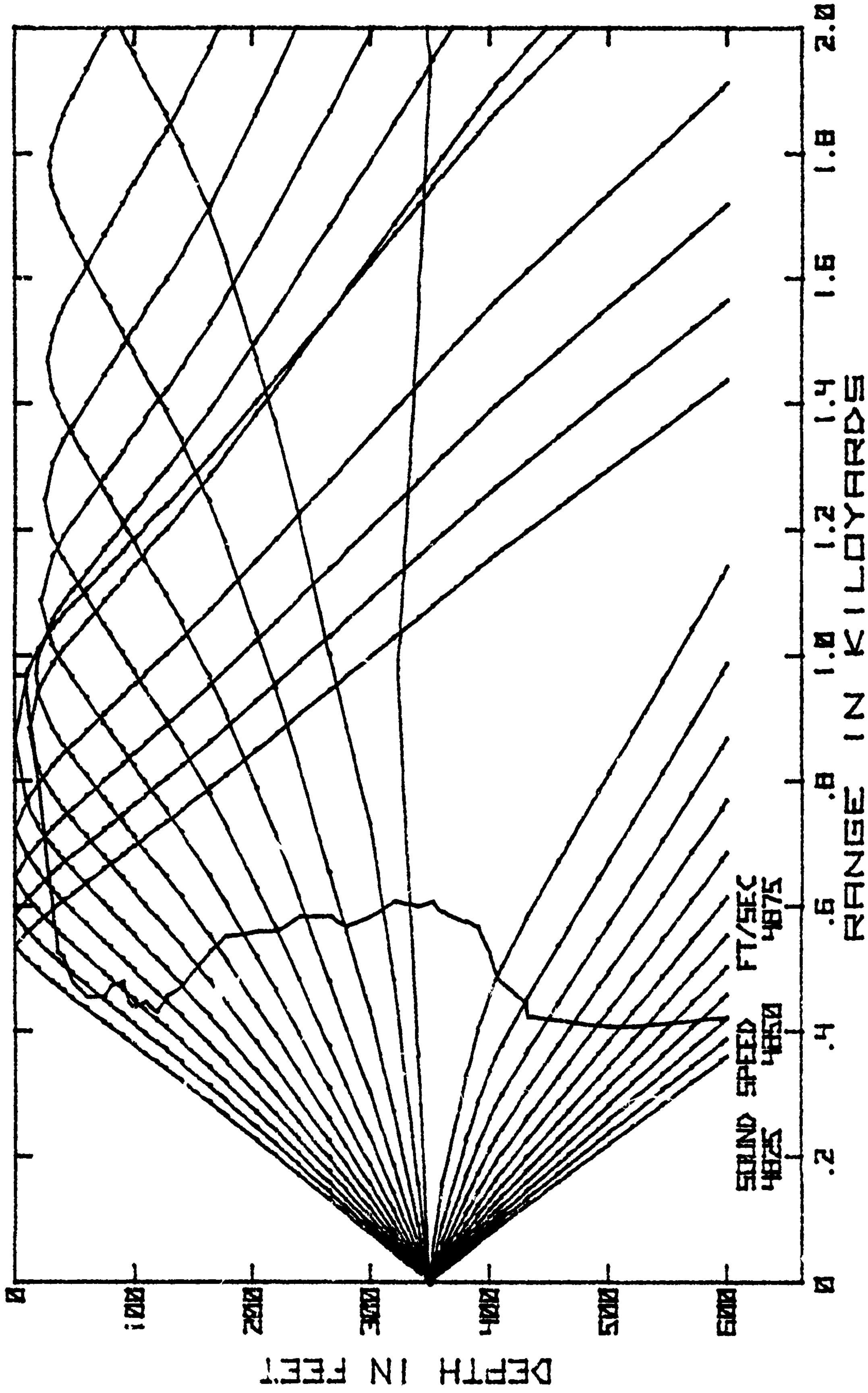

FIG. C-87. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 350 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

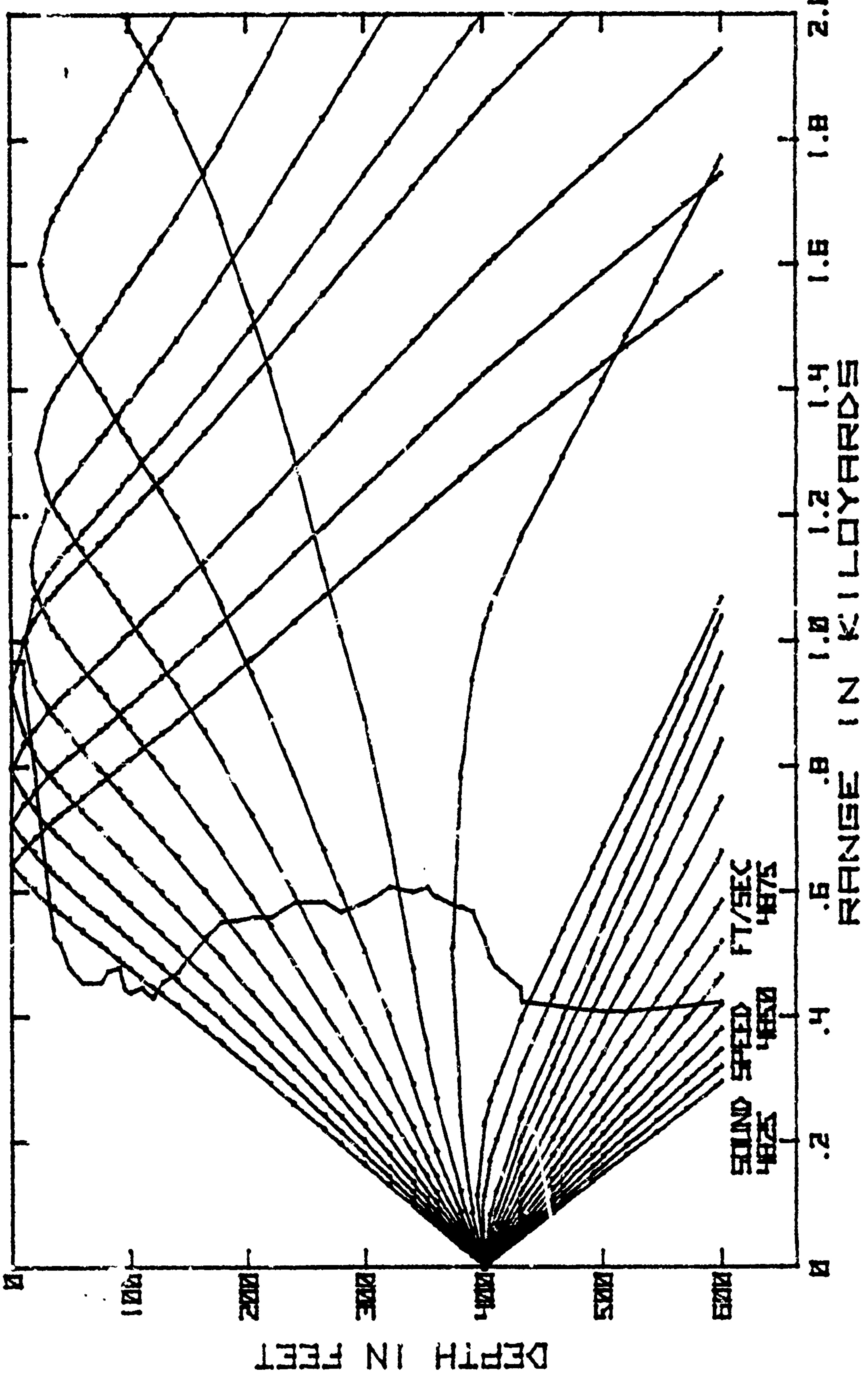

FIG. C-88. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 400 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

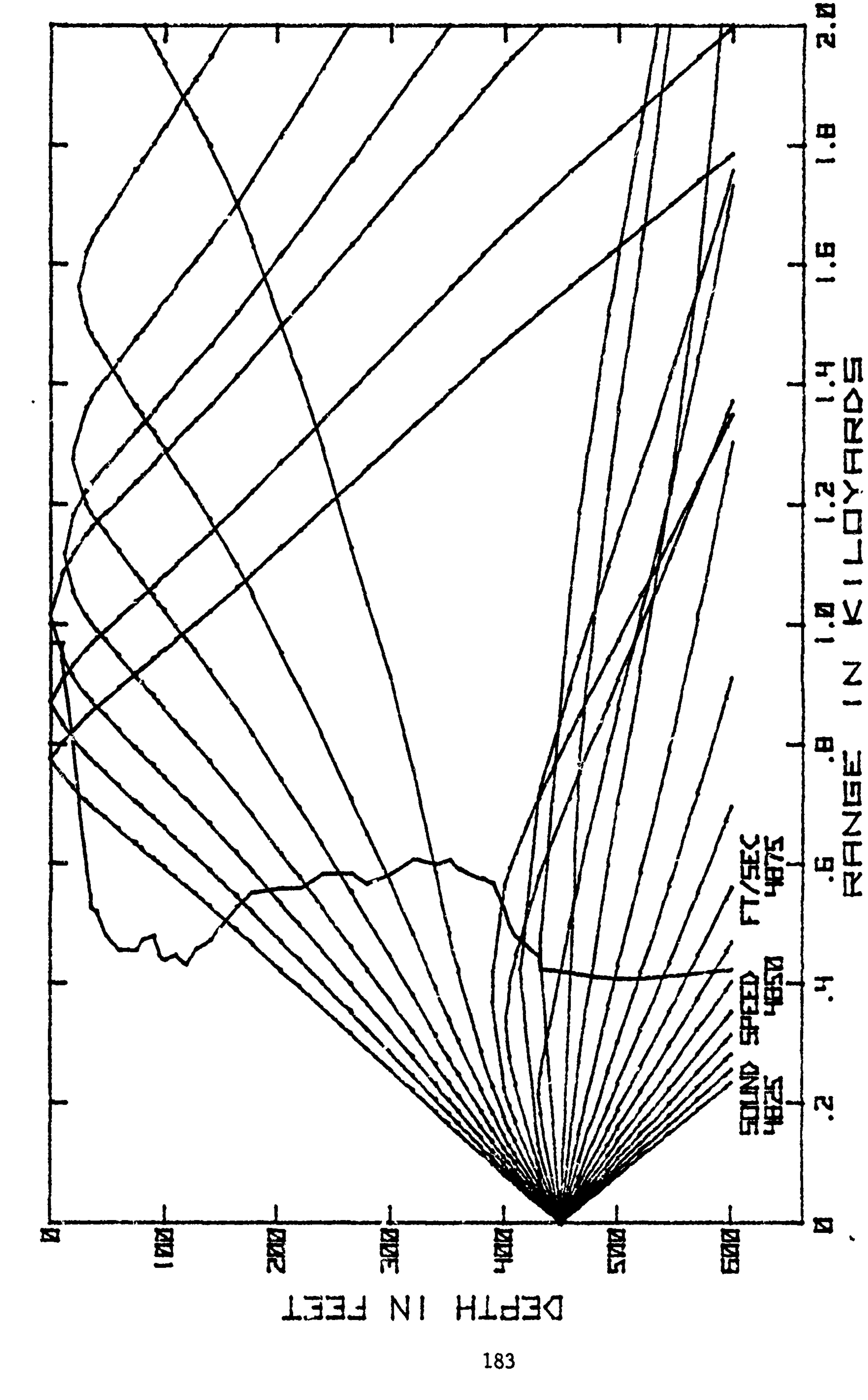

FIG. C-89. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 450 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

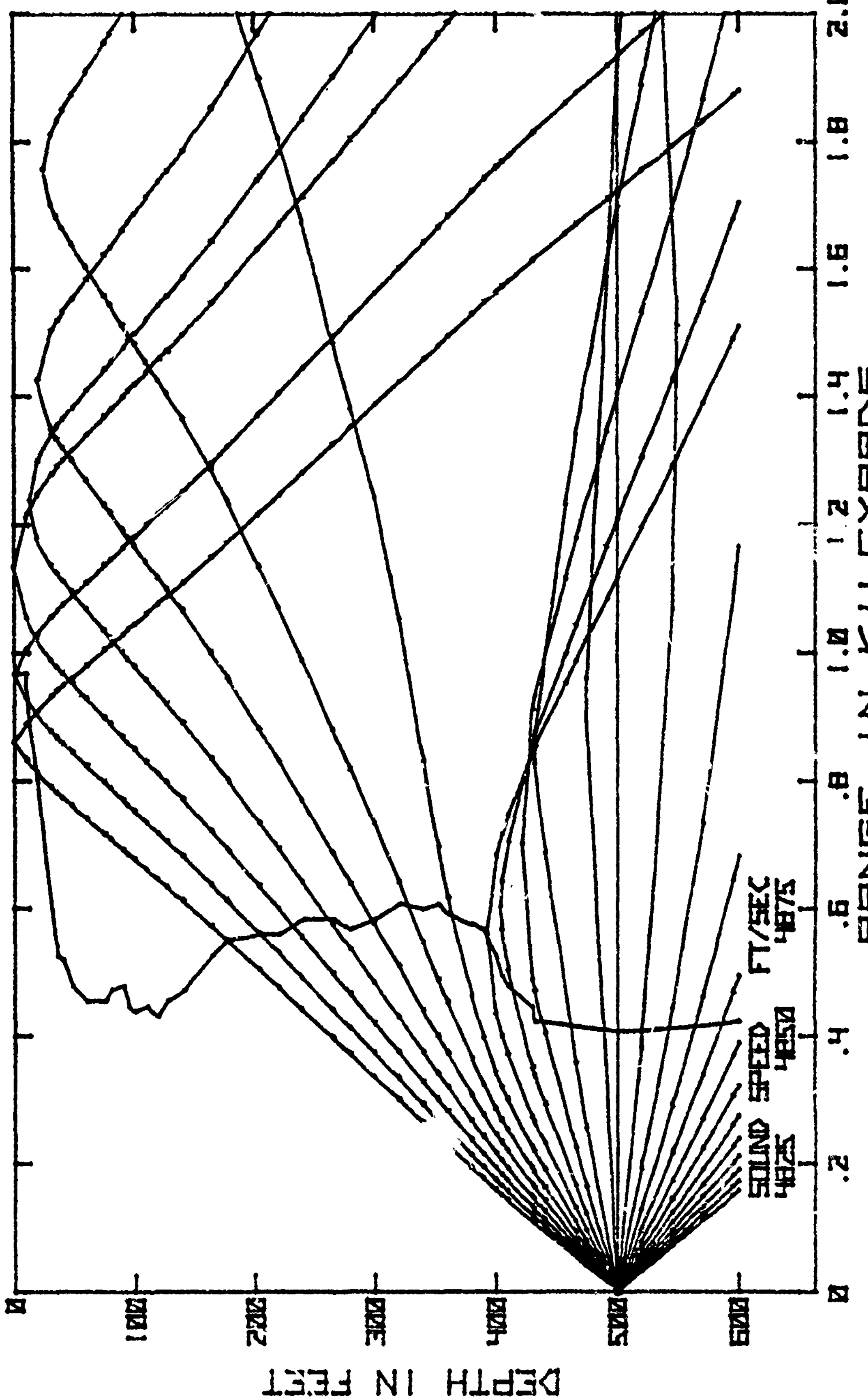

FIG. C-90. RAY DIAGRAM FOR SEPTEMBER SOURCE DEPTH 500 FEET
SOURCE ANGLES FROM 12 DEG DOWN TO 12 DEG UP IN 1 DEG INCREMENTS

Appendix D

CALCULATION OF TRANSMISSION LOSS

Smith's (BBN Report 1563, Part I) shallow water, depth-averaged estimate of the transmission loss *(TL)* between a source and receiver separated by a lateral distance *r* under conditions of (1) a reverberent field, (2) an isogradient sound speed profile, and (3) uniform channel conditions is given by the following formula.

$$TL = -10 \log \left\{ \left[\left(\frac{2\pi}{bD} \right)^{1/2} \frac{S_1^2}{r^{3/2}} e^{-\alpha_v r} \right] \left[e^{-\lambda/b} \right] \left[I \right] \right\}$$

where

$$\lambda = \frac{rb_s gd}{DC_o} - \frac{rb_b g(D - d)}{DC_o}$$

and

$$g = \frac{C_b - C_s}{D}$$

for a positive isogradient condition (see Figure D-1);

$$\lambda = \frac{rb_b g(D - d)}{DC_o} - \frac{rb_s gd}{DC_o}$$

and

$$g = \frac{C_s - C_b}{D}$$

for a negative isogradient condition (see Figure D-2);

b = total boundary reflection loss in nepers/radian, and

$$I = \frac{2}{\sqrt{\pi}} \int_{\phi_\ell}^{\pi/2\varepsilon} \exp \left\{ -1/2 \left[\phi_0^2 + \sqrt{\left(\phi_0^2 + \phi_m^2 \right)\left(\phi_0^2 - \phi_\ell^2 \right)} \right] \right\} d\phi$$

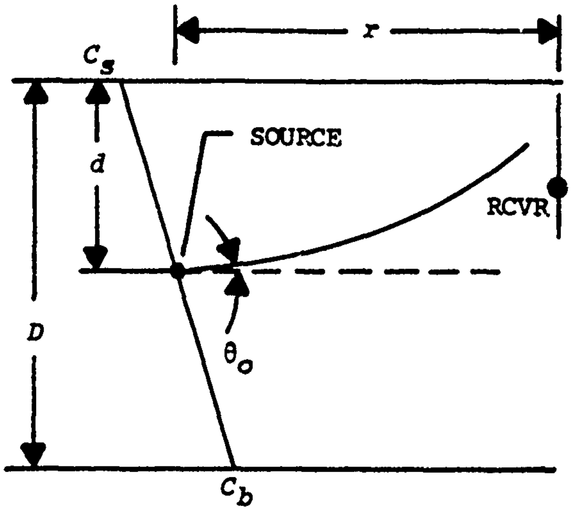

Figure D-1. Positive Isogradient

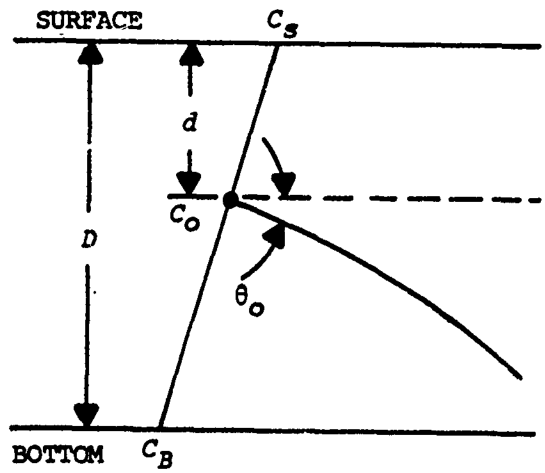

Figure D-2. Negative Isogradient

Contours of -10 log I or K using the normalized angles (see Figure D-3)

$$\phi_m = \left[\frac{brgd}{DC_o}\right]^{1/2} \text{ and } \phi_\ell = \left[\frac{brg(D - d)}{DC_o}\right]^{1/2}$$

θ_o = emanating ray source angle

C_s = sound speed at the surface (top of channel)

C_o = sound speed at the source depth d

C_b = sound speed at the bottom (bottom of channel)

$b = b_s + b_b$ the sum of the boundary reflection loss coefficients

b_s = surface reflection loss coefficient in nepers/radian/reflection

b_b = bottom reflection loss coefficient in nepers/radian/reflection

for small angles (<35°)

$$\sin \theta_b \cong \theta_b \text{ and } B_s = b_s \sin \theta_s,\ B_b = b_b \sin \theta_b$$

where

θ_s and θ_b are the grazing angles and B_s and B_B are the surface and bottom reflection losses in nepers/reflection.

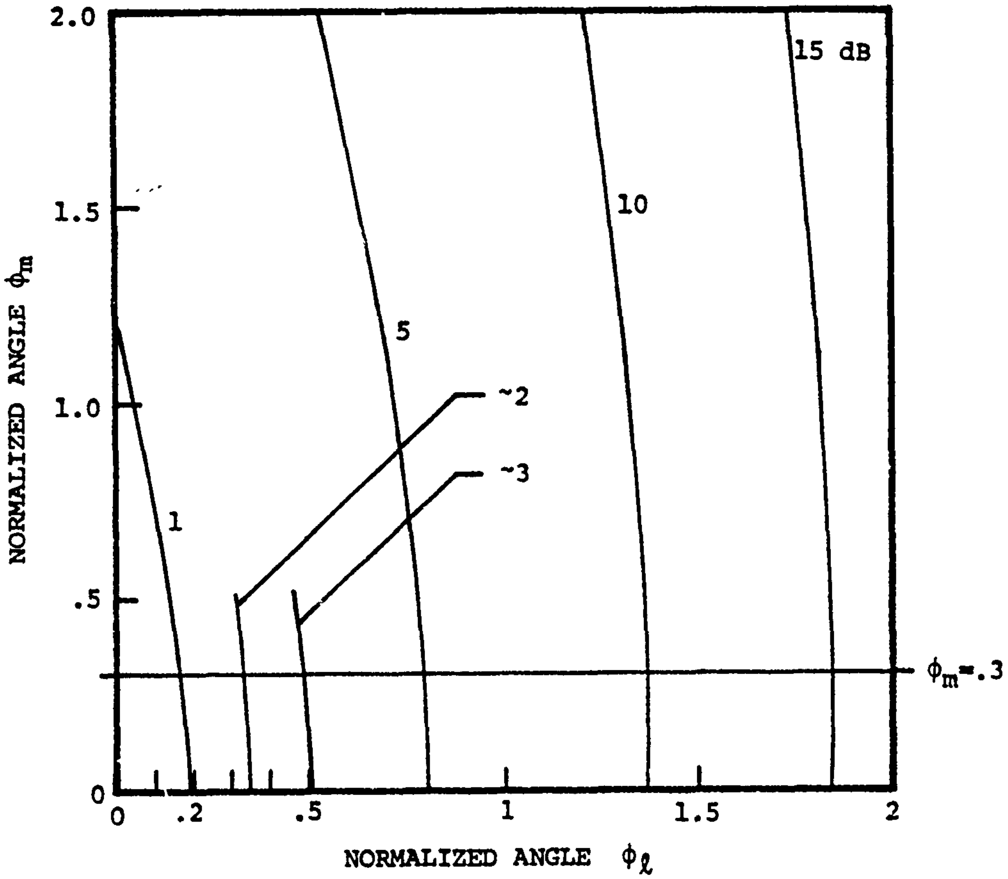

Figure D-3. Contours of -10 Log I

For Dabob Bay, BBN Report 1688 suggests

$$b_s = 0.3 \text{ and } b_b = 1.1,$$

resulting in b nominally equaling 1.4.

At lateral ranges of $r \lesssim 500$ yards, the magnitude of the last two terms in braces is less than 1 dB for all source and receiver depth combinations in the range $.95\ D \leq d \leq .5\ D$ and for "eyeball" equivalent sound speed gradients $(g) \lesssim \pm 0.075\ \text{sec}^{-1}$. Examples of "eyeball" equivalent iso-gradients for the five actual/typical sound speed profile conditions characterizing Dabob Bay are shown in Figures D-4 through D-8.

For all practical purposes the estimate of TL between a source and a single receiver separated by a lateral distance r under reverberent field conditions is

$$TL \cong 15 \log r + \alpha r + 5 \log b + 5 \log D - 4 + \lambda dB$$

substituting $b = 1.6$ and $D = 200$ yards (600-foot depth)

TL becomes $15 \log r + \alpha r + 8.5 + \lambda$dB

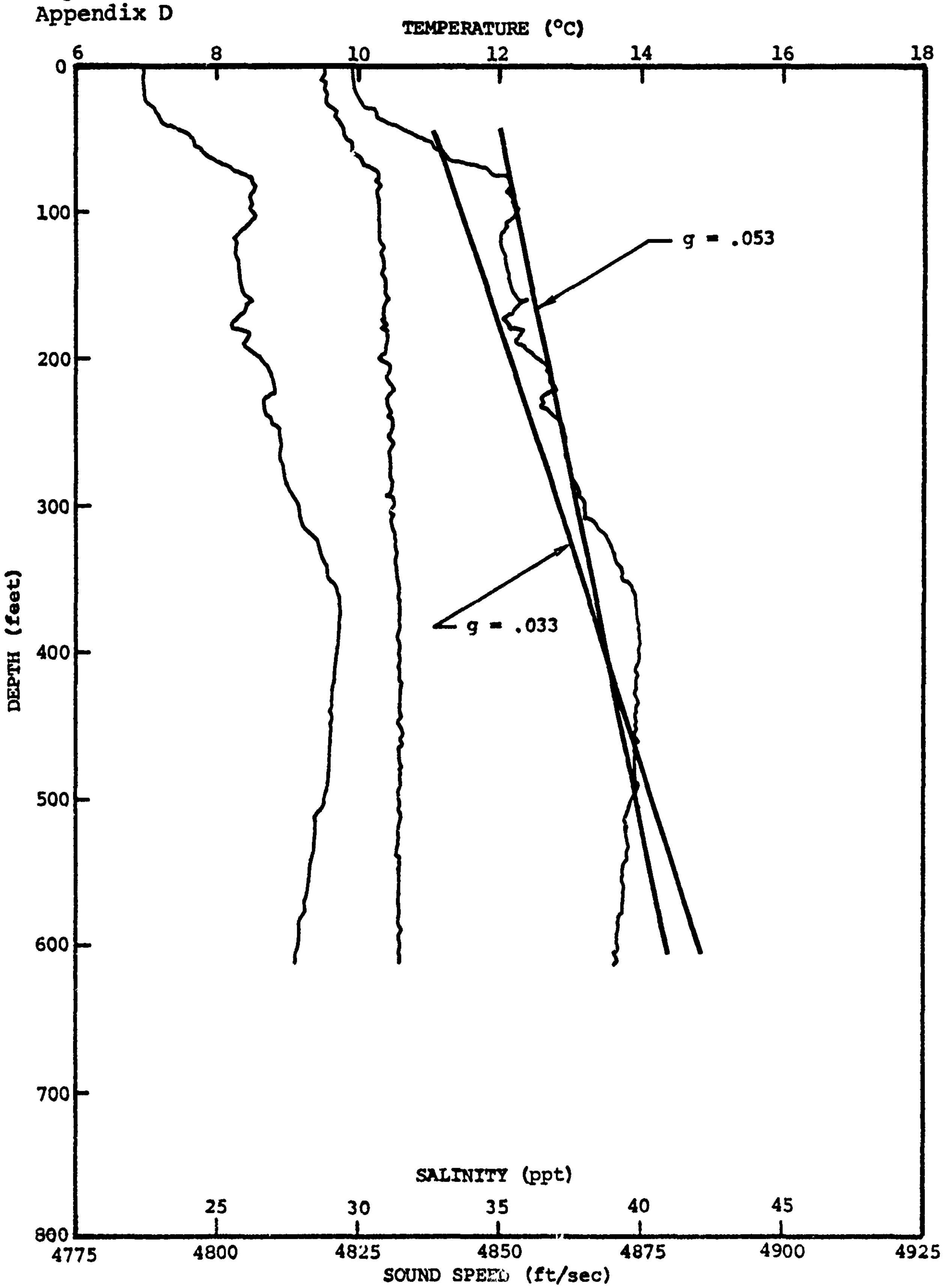

Figure D-4. Sound Speed/Temperature Salinity Profile
Dabob Bay Range, 1-18-71

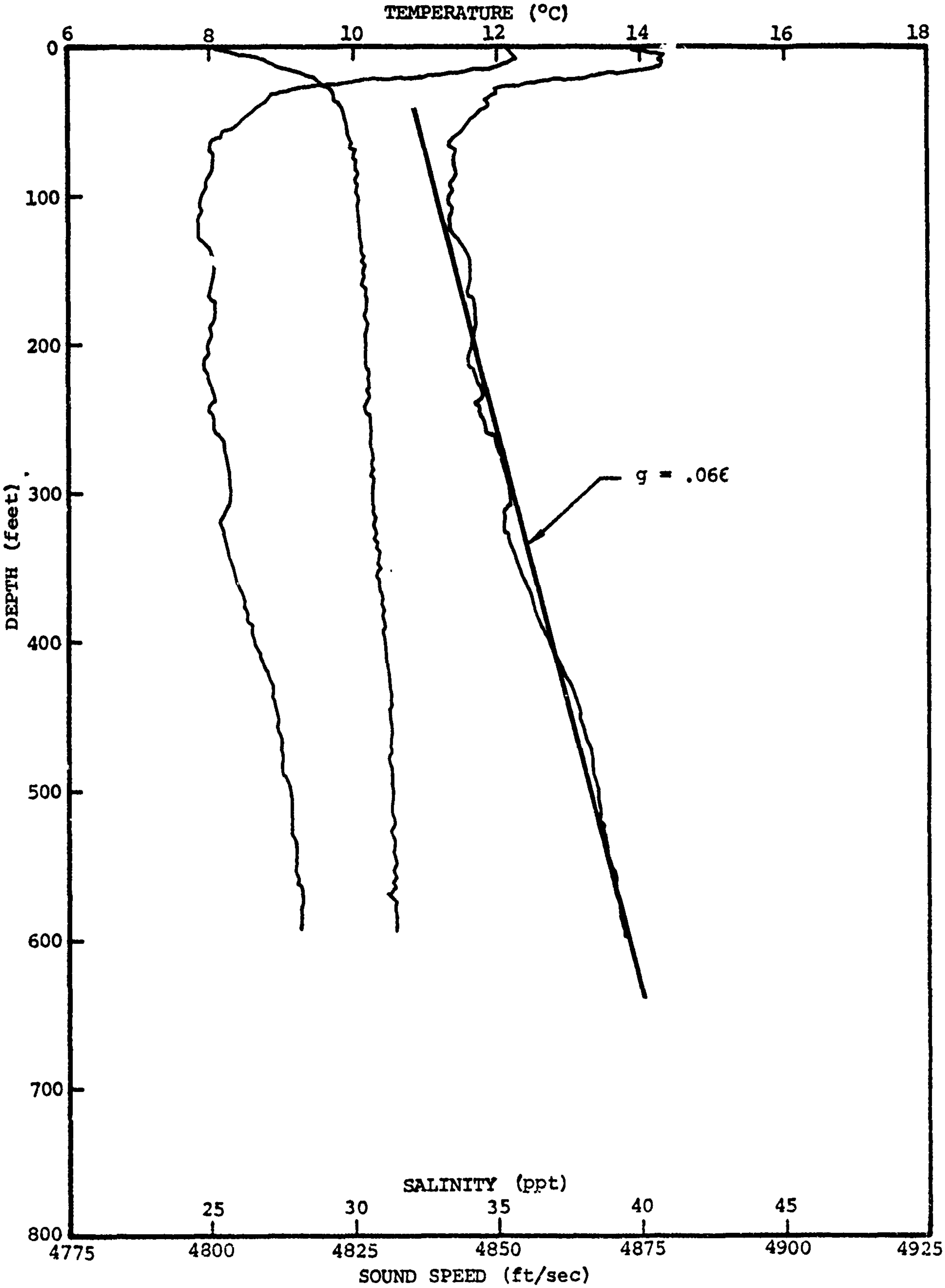

Figure D-5. Sound Speed/Temperature Salinity Profile
Dabob Bay Range, 5-10-71

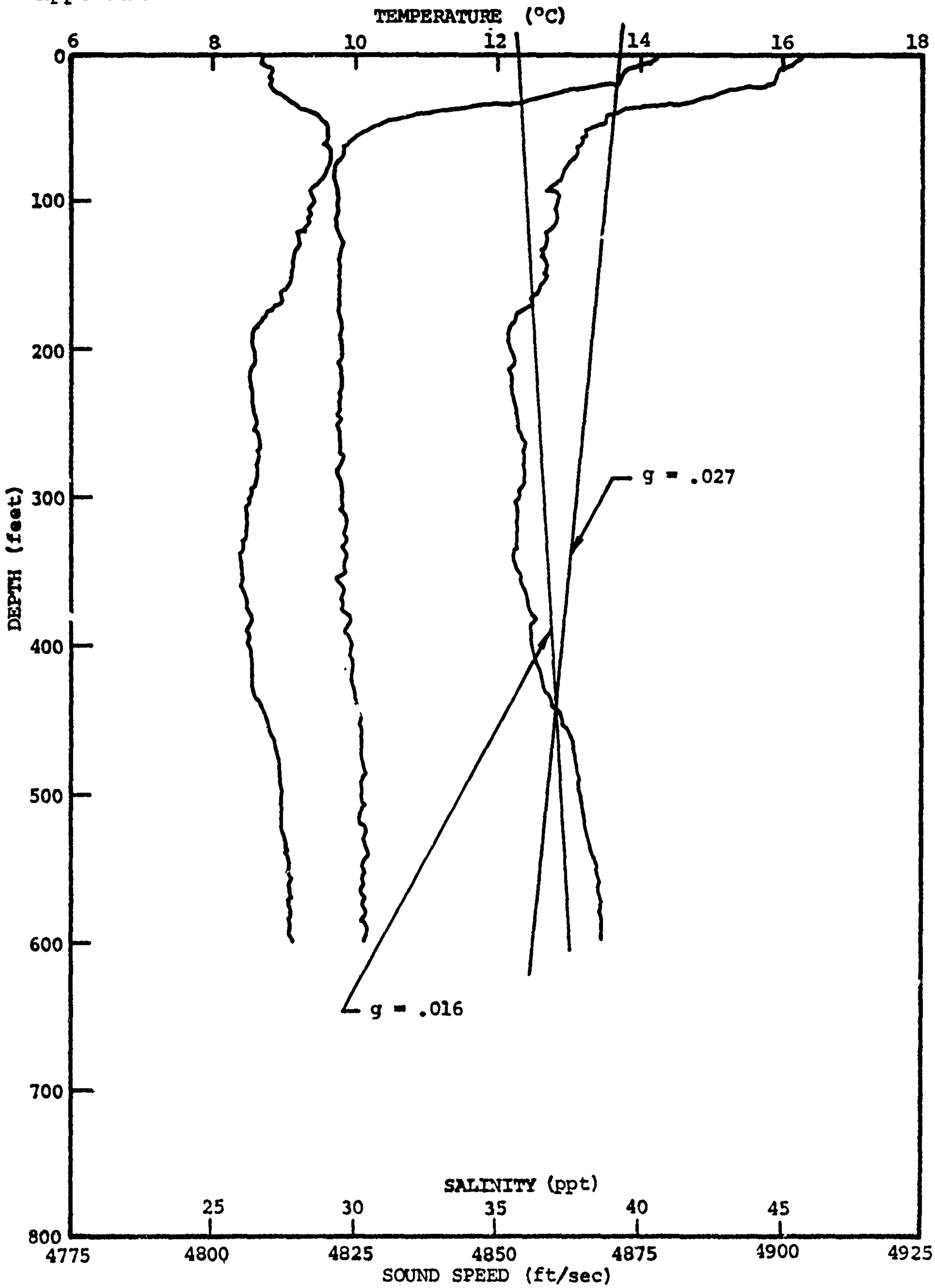

Figure D-6. Sound Speed/Temperature Salinity Profile
Dabob Bay Range, 7-12-71

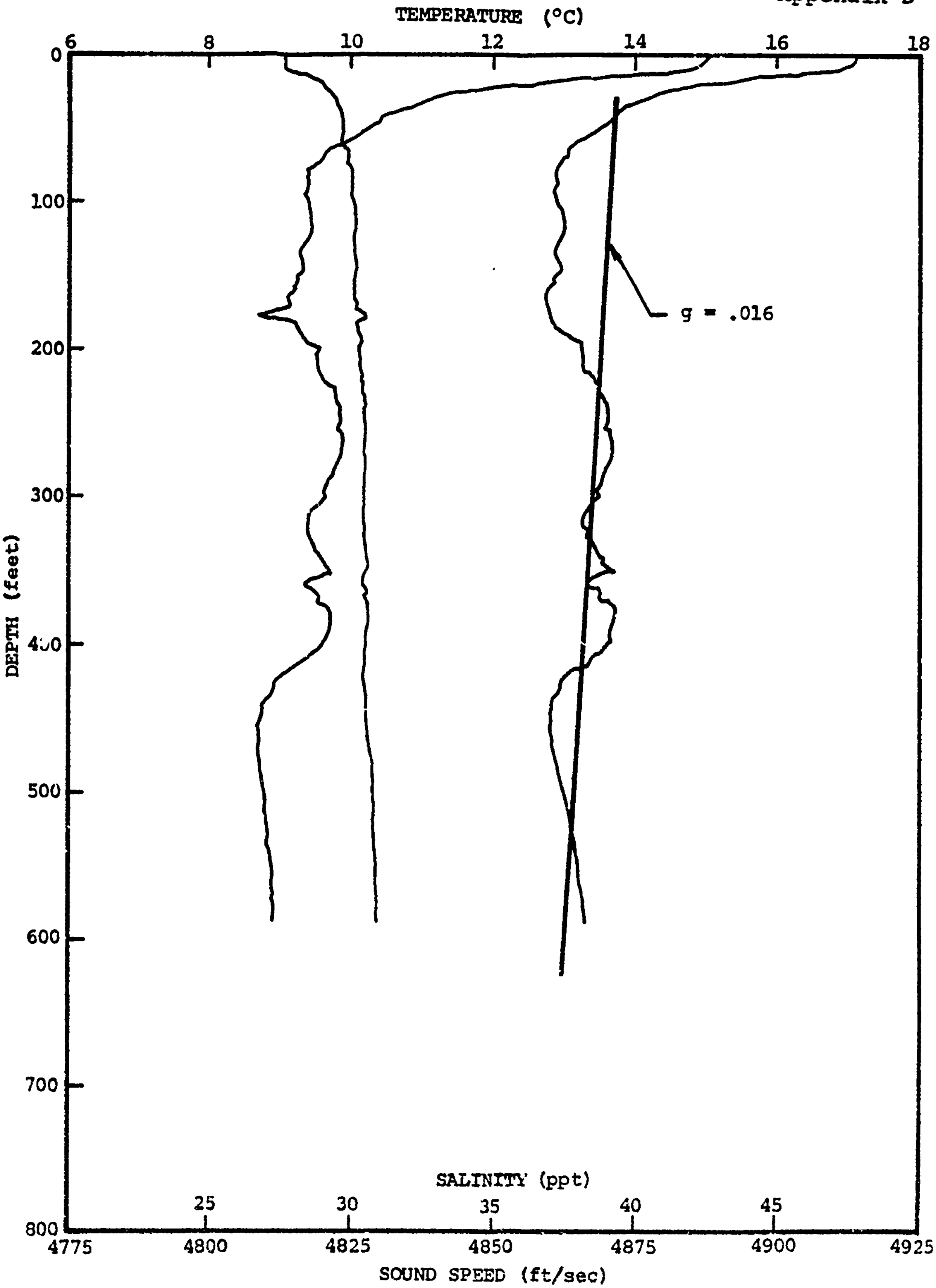

Figure D-7. Sound Speed/Temperature Salinity Profile
Dabob Bay Range, 9-10-71

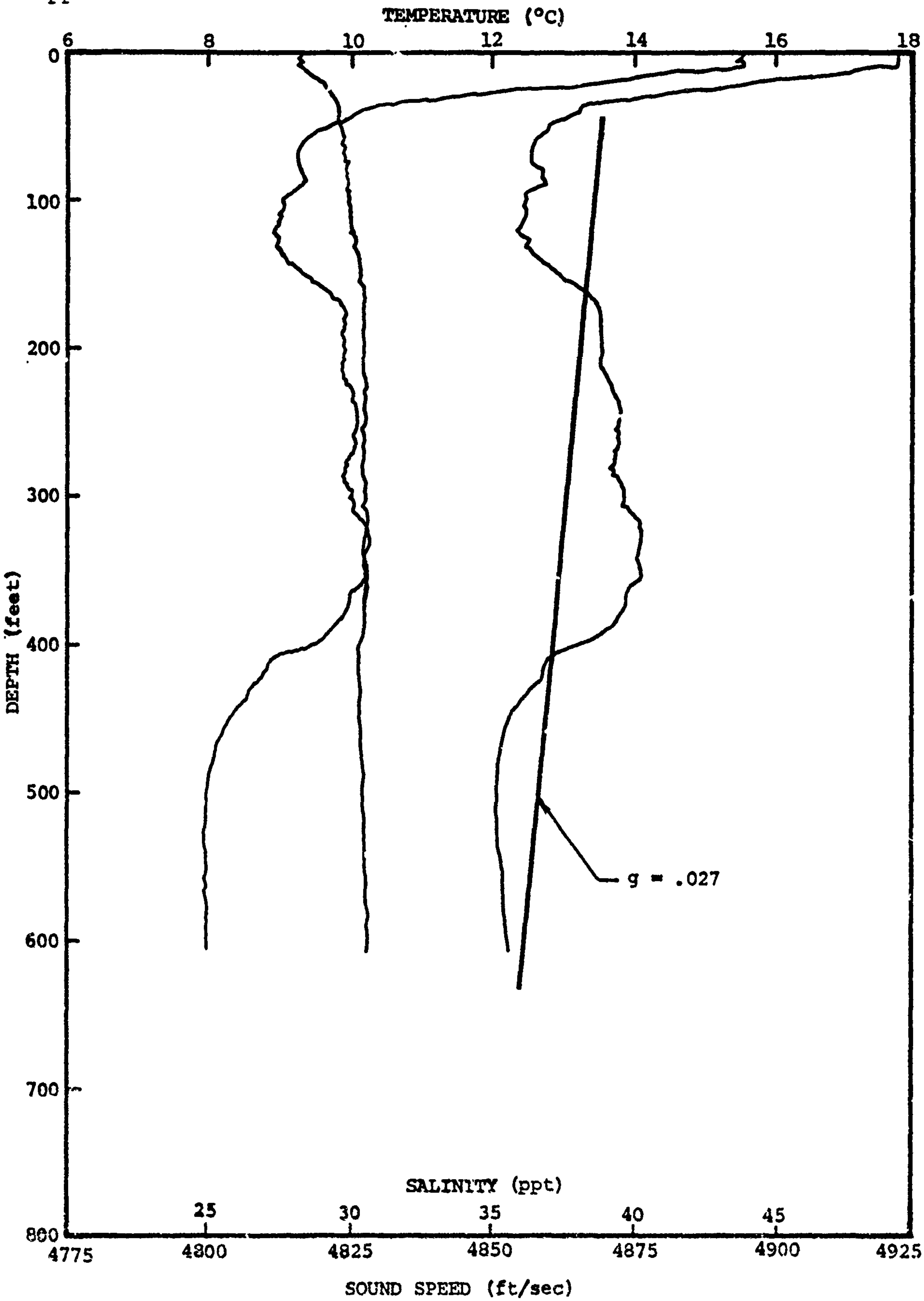

Figure D-8. Sound Speed/Temperature Salinity Profile
Dabob Bay Range, 9-13-72

The sensitivity of this equation to variations in b and D such as $1.4 \leq b \leq 1.9$ and $500 \leq D \leq 600$ feet is <0.5 dB. As noted earlier λ is less than 1 dB for $r \leq 1500$ feet and $300 \leq D \leq 570$ feet.

The word "estimate" as used in this appendix is deserving of further elaboration. Consider the geometry shown in Figure D-9.

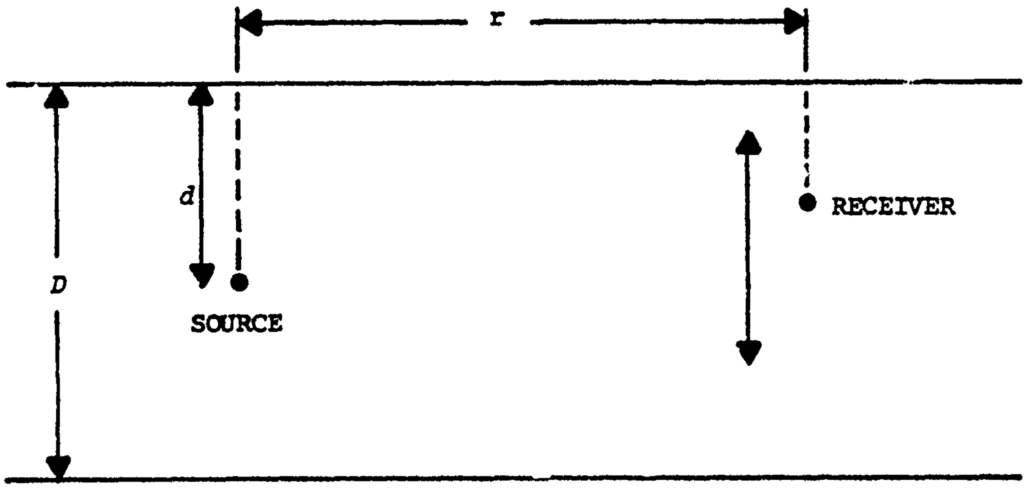

Figure D-9. Source and Single Hydrophone Receiver Geometry

If the receiver were positioned at various depths and the readings of sound pressure at these depths were averaged it would be found that the ratio of sound pressure levels

$$\left[\frac{\text{(depth averaged)}}{\text{(source level)}}\right]$$

would be described by

$$TL = 15 \log r + \alpha r + 8.5 + \lambda dB.$$

Although this equation was derived on the basis of isogradient and constant channel characteristics wherein the bottom reflection loss was areally constant and channel depth invariant (i.e., no bottom slopes), its application to Dabob Bay is reasonable at short ranges even though none of the above conditions are met *if* sufficient vertical averaging of the sound field at distance r is accomplished.

At short ranges ($r \leq 1500$ feet) the reflected/reverberent field is essentially unaffected by either the existent bottom slopes in measurement areas of interest and is only slightly affected by marked changes in either the surface or bottom reflection loss. The ray diagrams in Appendix C demonstrate the potential seriousness of acoustic refraction on the sound field that is not reflected/reverberent. Also to be considered is surface reflected (Lloyd mirror) interference. Figures D-10 through D-12 illustrate the reflected or reverberent field rays and Appendix C illustrates the possibilities for lower sound pressure regions caused by refraction. Both of these effects are minimized but not eliminated by asymmetrically spaced hydrophones (for Lloyd mirror effect reduction and spatial averaging).

Although not ordinarily part of an oceanographic range user's guide the following environmental conclusions are pertinent:

1. The effects of sound ray refraction are greatest when the sound measurement hydrophone is at or near the running depth of the device under test.

2. Bolt, Beranek, and Newman has gained experimental verification of the validity of its transmission loss equation. Per BBN Report 1688, the accuracies obtained with a three-element asymmetrically spaced vertical array should fall within a range of the 15 log *r* trend such that the standard deviation is less than 3 dB.

Study of obtained data by experienced personnel will uncover measurement condition problems and allow systematic reduction of the confidence interval in which the mean absolute level must reside.

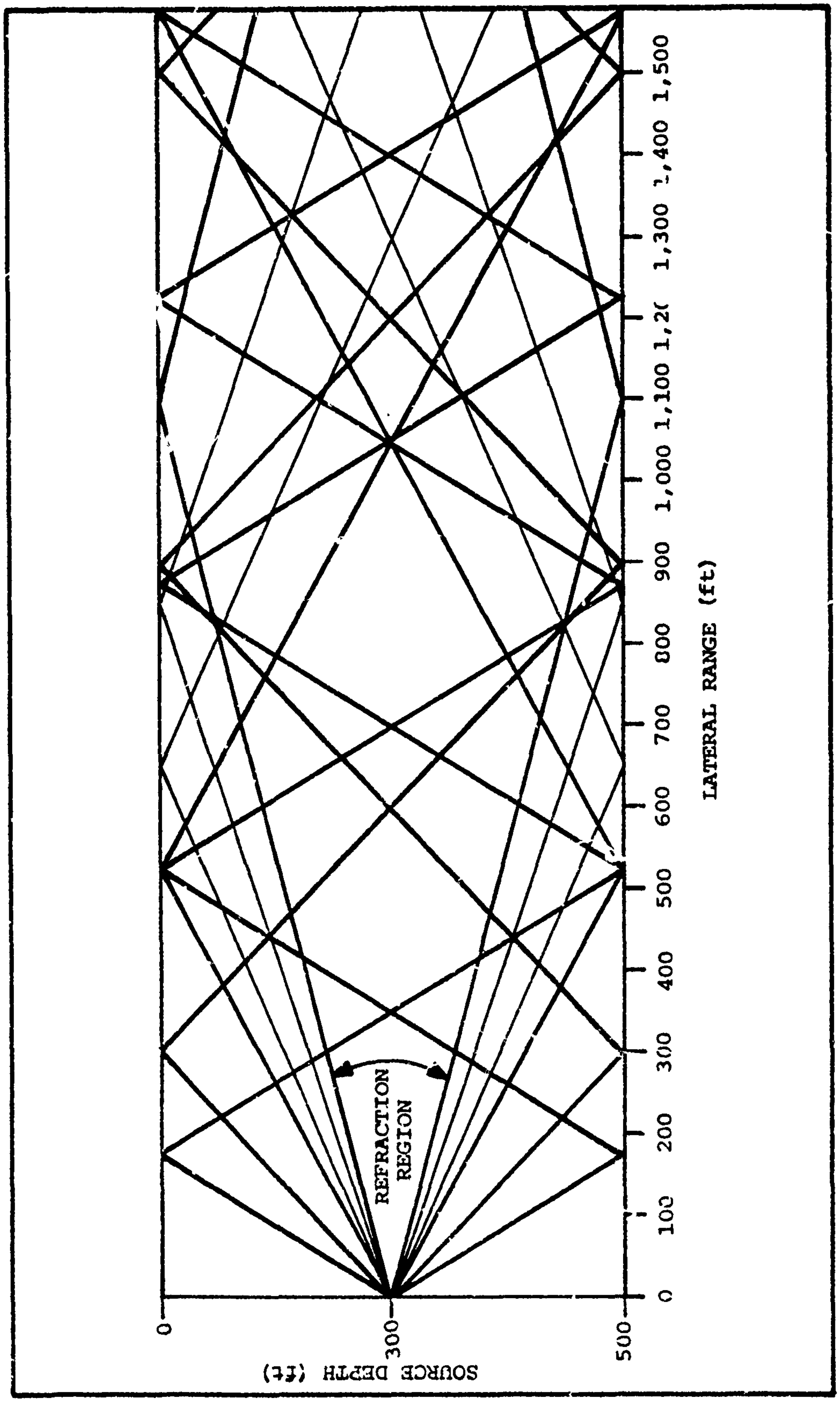

Figure D-10. Classical Reverberent Rays for "0" Bottom Slope

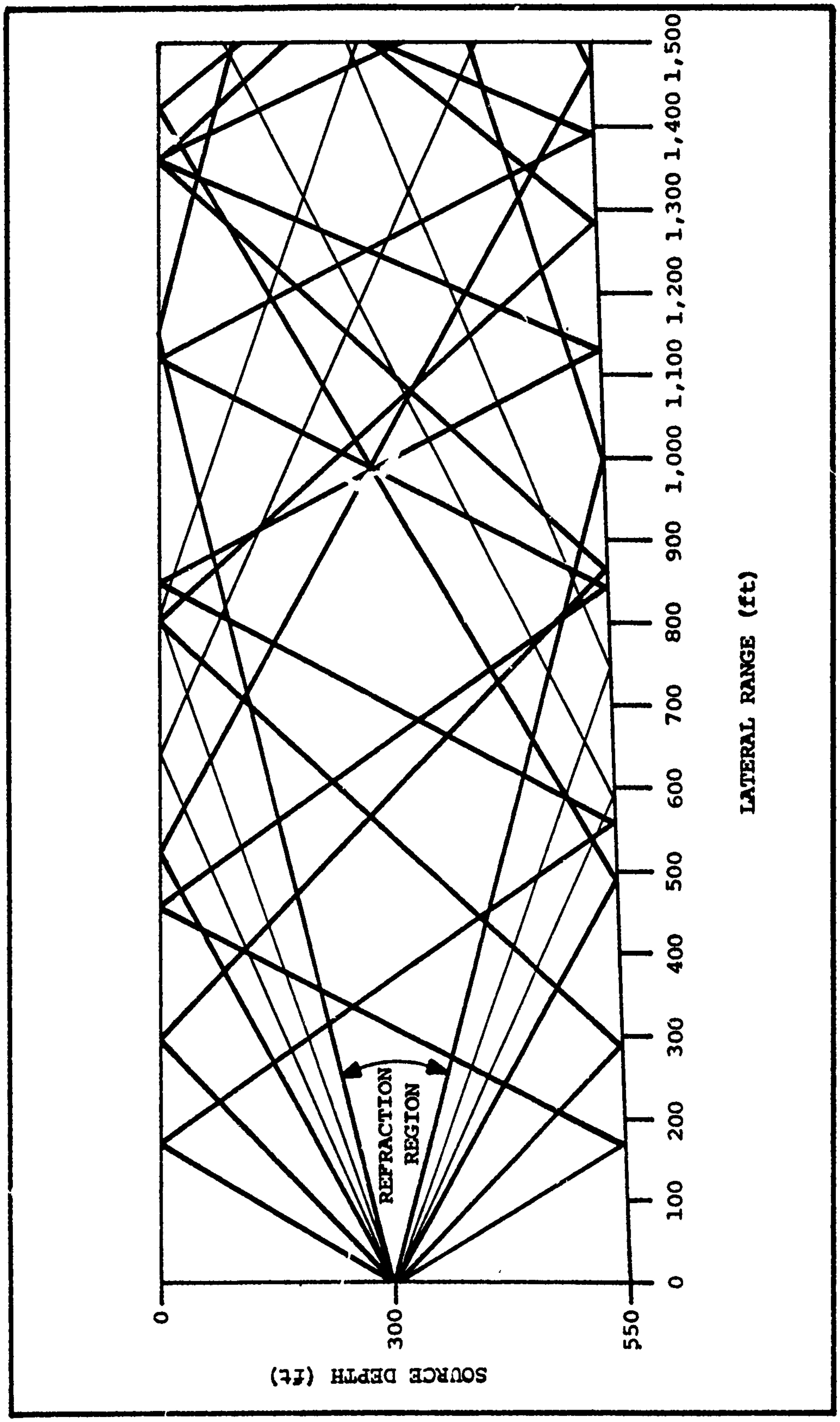

Figure D-11. Classical Reverberent Rays for Sloping (50'/1500') Depth Decreasing Bottom

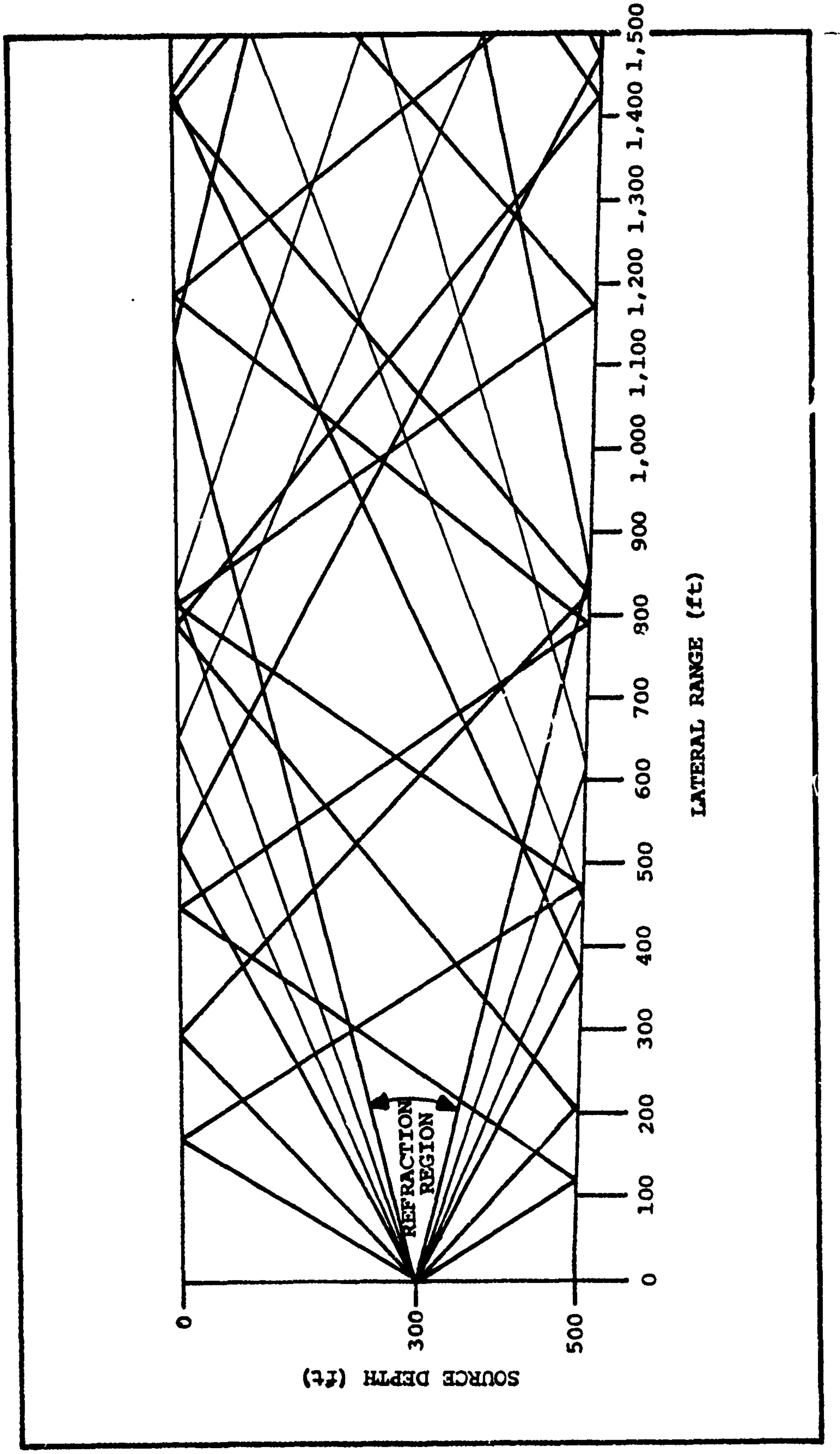

Figure D-12. Classical Reverberent Rays for Sloping (50'/1500') Depth Increasing Bottom

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